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# NASA Technical Memorandum 83273

(NASA-TM-83273) THE 1981 DIRECT STRIKE  
LIGHTNING DATA (NASA) 40 P HC A03/HF AC1  
CSCL 04B

882-22848

Unclass

G3/47 09579

## 1981 DIRECT STRIKE LIGHTNING DATA

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March 1982



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## 1981 DIRECT STRIKE LIGHTNING DATA

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### SUMMARY

This report presents the results obtained during the 1981 direct-strike lightning tests of the NASA Langley Research Center lightning-instrumented F-106B aircraft. The tests were conducted in the vicinity of the National Severe Storms Laboratory, Norman, Oklahoma, and in the vicinity of the NASA Langley Research Center, Hampton, Virginia. The entire strike data obtained for 10 strikes in the 1981 test series are presented in this report.

### SYMBOLS

$\dot{B}$	rate of change of magnetic flux density, tesla per second
$\dot{D}$	rate of change of electric flux density, ampere per square meter
$\dot{I}$	rate of change of current, ampere per second
$E_z$	static electric field, volt per meter
$A/m^2$	ampere per square meter
m	meter
T/s	tesla per second
P-P	peak-to-peak

### INTRODUCTION

This report presents the direct-strike lightning data obtained in 1981 during lightning flight tests of the NASA Langley Research Center lightning-instrumented F-106B aircraft. There were 10 pilot reported strikes to the

aircraft during these flights; there were also 10 strikes in the 1980 tests which were reported in reference 1. The instrumentation system, transient recorders, sensors, and a summary overview of the 1980 tests are presented in references 2, 3, 4, and 5, respectively.

#### 1981 LIGHTNING DATA

The 1981 test series resulted in 10 pilot reported direct strikes to the aircraft from 22 storm penetration flights. Table 1 summarizes the 1981 data recorded and particulars concerning data acquisition. The entries under the D-dot FWD and B-dot LONG (abbreviated  $\dot{D}_F$  AND  $\dot{B}_L$  in the table) are the number of 1310 microsecond records acquired during strikes and nearby strikes from the D-dot forward and B-dot longitudinal sensors at 10-nanosecond sample intervals. Twenty-seven transient waveforms were recorded and are presented in this report. Fourteen transients were recorded during flight 81-026 during one test made with the instrumentation system gain adjusted to record free-field aircraft excitation (not attached lightning) to aid in data interpretation of aircraft resonances, etc.

No direct strike D-dot data were obtained during the 1981 tests for flights 81-036 — 81-043 due to undetected failure of an attenuator in signal conditioning circuitry (noted by dashes in table 1). There was one strike to the aircraft reported during flight 81-036, one during 81-039, four during 81-040, one during flight 81-042 and two during 81-043. The attenuator failure also resulted in B-dot loss for flight 81-036 — 81-040 since the B-dot recorder trigger was controlled by the D-dot recorder for these three flights. The tenth pilot reported strike of the season occurred during flight 81-046 on 9/8/81. The  $\dot{B}_L$  data recorded on this flight was of insignificant amplitude (approximately one least significant bit of the digital transient recorder) and is not presented. Neither the  $\dot{D}_F$  nor I recorders were triggered by this strike.

Figures 1 through 28 are the data waveforms obtained in the 1981 flight tests. The single current waveform shown in figure 28 was obtained for a pitot boom strike recorded by the Boeing Company developed data logger described in reference 6. The sign conventions established for the measurements shown in figure 29 indicate positive quantities in the direction of the arrows; the relation between the sign conventions of the variables  $D$ ,  $B$ , and  $I$  and their derivatives are shown in the measurement polarity time history also in figure 29. There were two transient recorders; these were connected to the  $B$ -dot sensor at (6) and the  $D$ -dot sensor at (2). All of the  $B$ -dot and  $D$ -dot data reported in this paper are from these two sensors; the  $I$  data are from a sensor located at (1). The location of the lightning attachment points and lightning paths for flights 81-042 and 81-043 are shown in figures 30, 31, and 32. Figure 33 is a composite showing the temporal relationship between  $B$ -dot (figure 19), and  $I$  (figure 28) for the boom strike of flight 81-043 for sensors located at (6), (3), and (1) on figure 29. ( $E_z$  is the vertical electric field obtained by the field mill system which is described in reference 7).

The 1981 data set includes transients recorded for a number of lightning events which were not reported by the pilot as strikes to the aircraft, as in figures 16-18 and 20-27. The only measurement of pilot reported direct lightning attachment occurred during flight 81-043 (figures 19, 28, 31) when the current,  $I$ , in the pitot boom was recorded by the aforementioned Boeing Company developed data logger. Even though post-flight examinations of the aircraft reveal that all ten lightning attachments in 1981 were initially to the pitot boom, the magnitude of current in the boom was below the measurement system threshold of 6000 amperes in every case except flight 81-043.

## REFERENCES

1. Pitts, Felix L.; and Thomas, Mitchel E.: 1980 Direct Strike Lightning Data. NASA TM 81946 Feb., 1981.
2. Thomas, Mitchel E.: Direct Strike Lightning Measurement System, AIAA/SETP/SFTE/SAE, 1st Flight Testing Conference, Las Vegas, Nevada, Nov. 1981. AIAA 81-2513.
3. Thomas, Robert M., Jr.: Expanded Interleaved Solid-State Memory of a Wide Bandwidth Transient Waveform Recorder. NASA CP-2128, FAA-RD-8-30. Lightning Technology, NASA Langley Research Center, April 22-24, 1980. p. 119.
4. Trost, Thomas F.; and Zaepfel, Klaus P.: Broadband Electromagnetic Sensors for Aircraft Lightning Research. op. cit., p. 131.
5. Pitts, Felix L.: Electromagnetic Measurement of Lightning Strikes to Aircraft. AIAA 19th Aerospace Sciences Meeting, St. Louis, Mo., Jan. 1981. AIAA-81-0083.
6. Von Bokern, G. J.; Piszker, L. D.; and Brick, R. D.: In-Flight Lightning Data Measurement System for Fleet Application, FAA-RD-28-83, FAA/Georgia Institute of Technology Workshop on Grounding and Lightning Protection. May, 1978, pp. 345-363.
7. Fitzgerald, D. R., and Byers, H. R.: Aircraft Electrostatic Measurement Instrumentation and Observations of Cloud Electrification, Final Report, Contract A. G. 19 (604)-2189, A.G.C.R.L./T.R./62/805, 1962.

TABLE I - 1981 LIGHTNING DATA SUMMARY

DATE	FLIGHT NO.	NO. STRIKES	D <sub>F</sub> (SENSOR LOCATION 2)	B <sub>L</sub> (SENSOR LOCATION 6)	I (SENSOR LOCATION 1)
7-1	81-026	0	10 <sup>(1)</sup>	4 <sup>(2)</sup>	0
8-6	81-041	0 (NEARBY)	-	2	0
8-11	81-042	1	-	1	0
8-16	81-043	1 (BOOM)	-	1	1 <sup>(3)</sup>
		1	-	3	0
9-8	81-045	0 (NEARBY)	0	5	0

(1) Recorder sensitivity increased 40dB

(2) Recorder sensitivity increased 20dB

(3) Recorded by Boeing data logger

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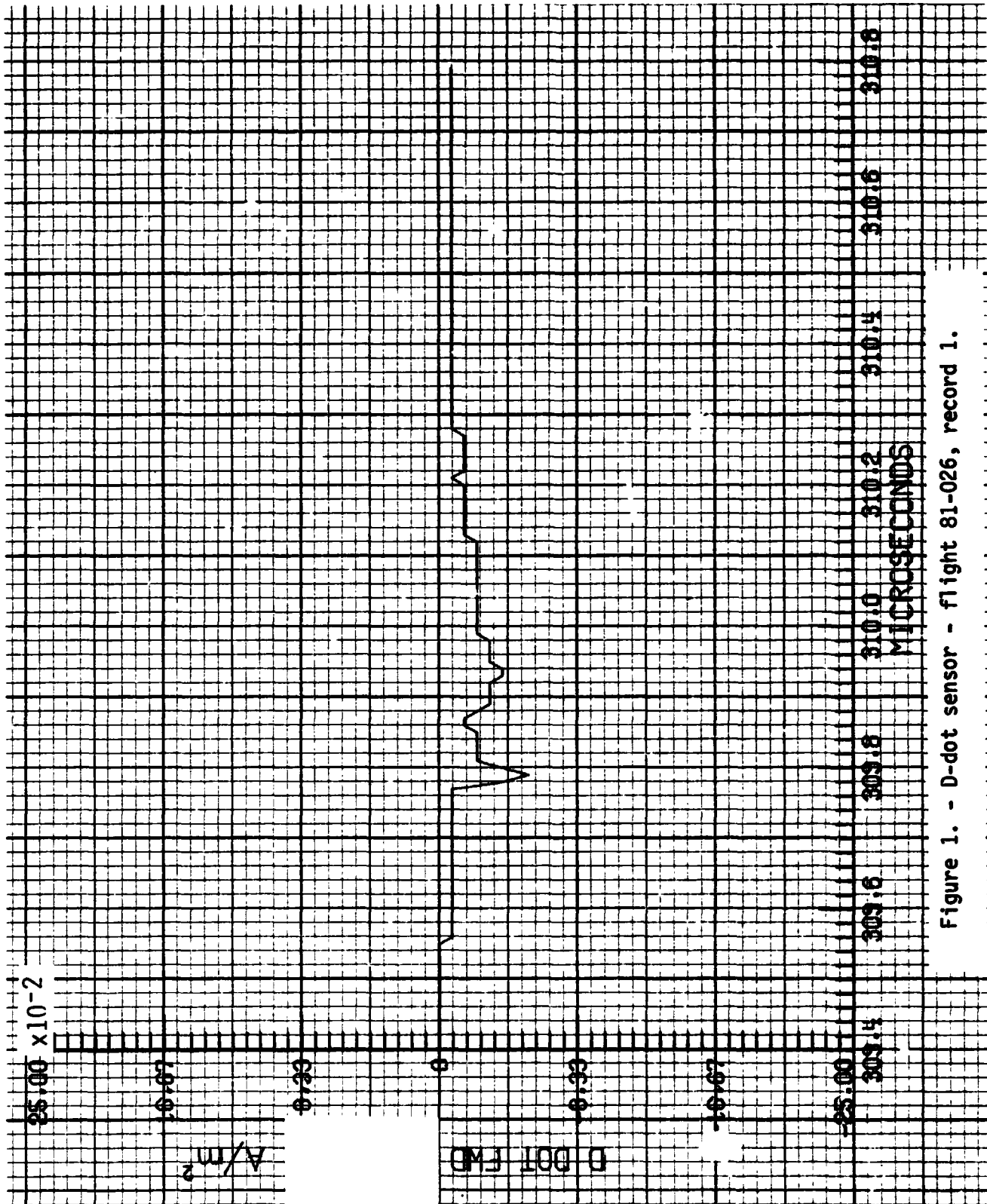


Figure 1. - D-dot sensor - flight 81-026, record 1.

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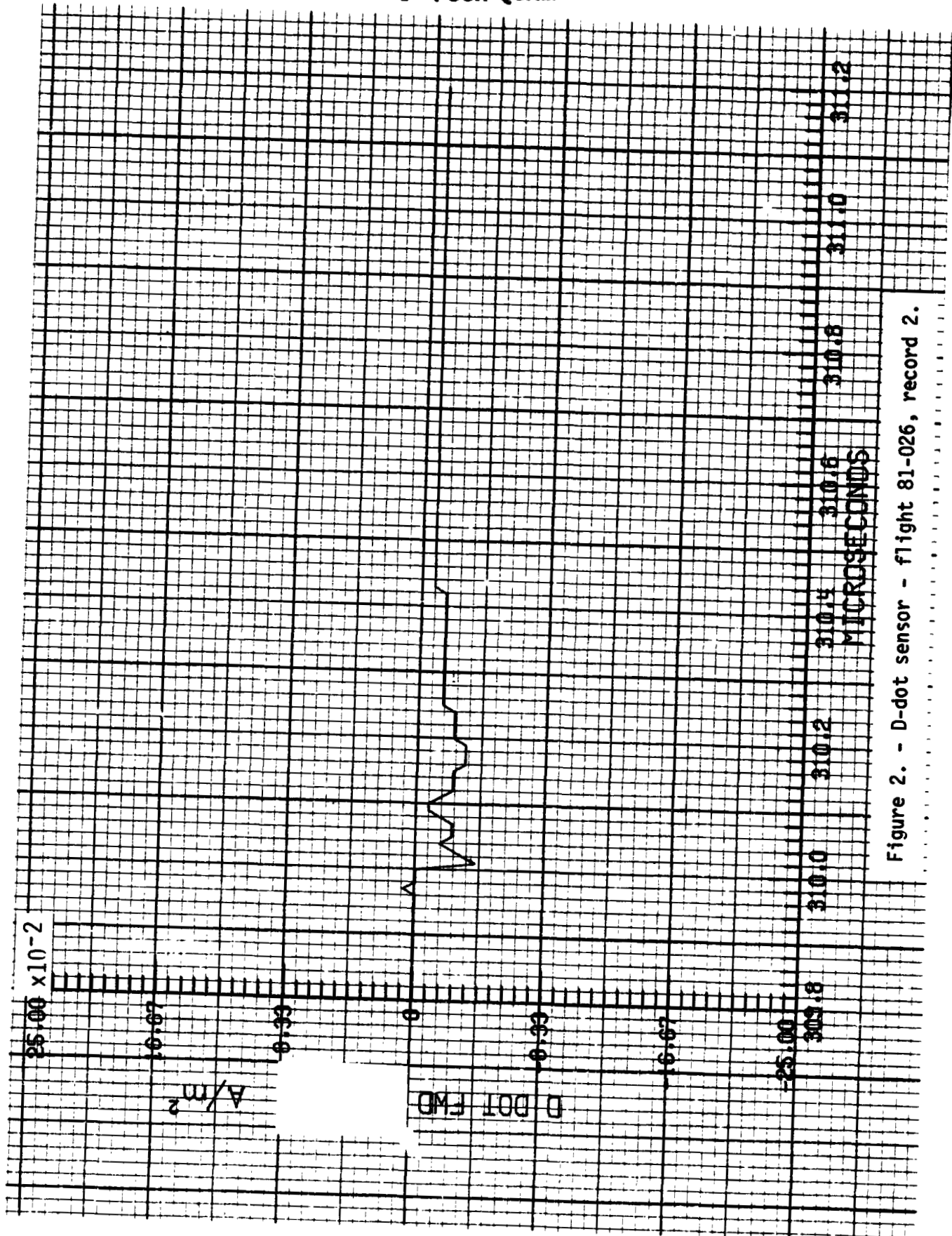


Figure 2. - D-dot sensor - flight 81-026, record 2.



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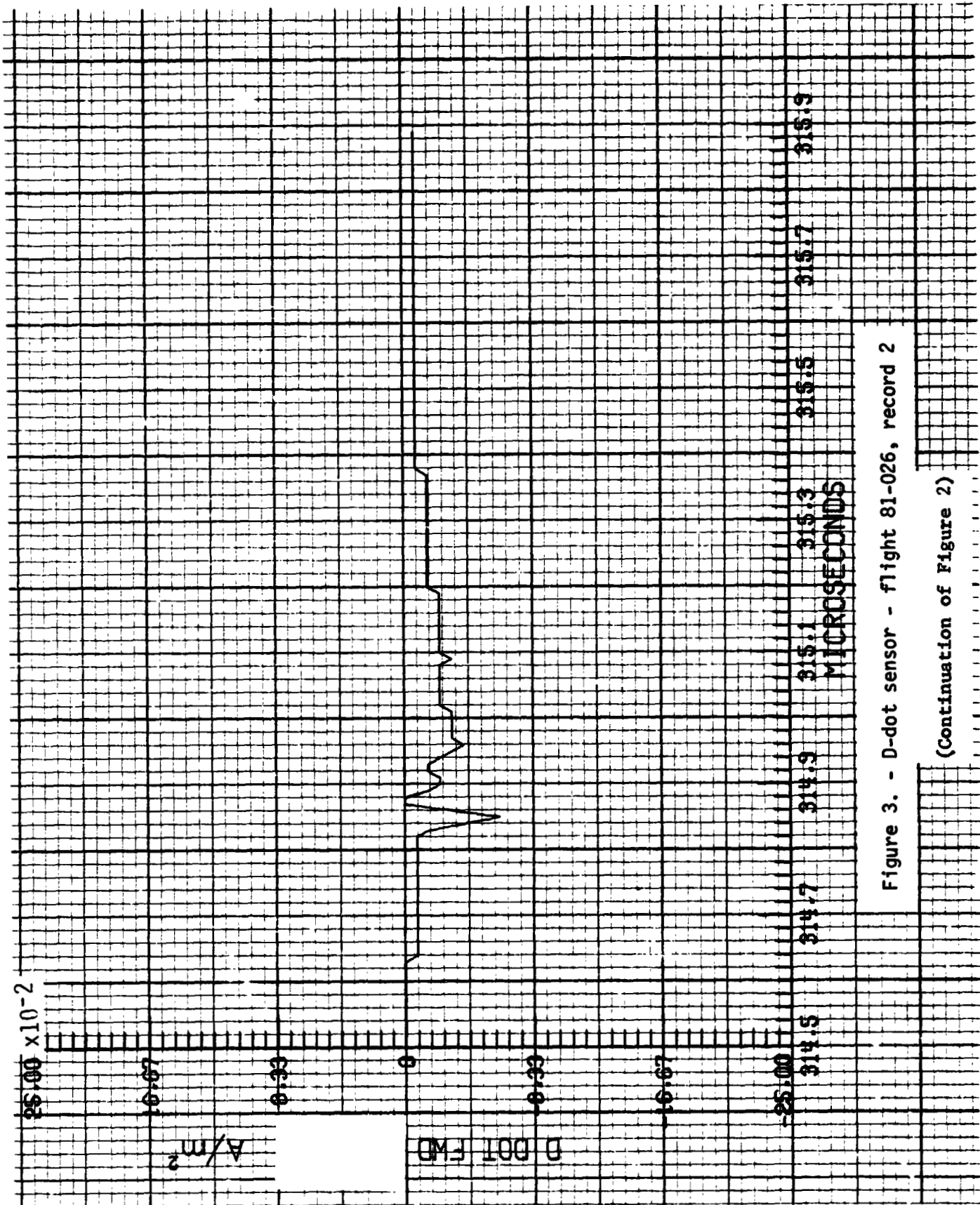


Figure 3. - D-dot sensor - flight 81-026, record 2

(Continuation of Figure 2)

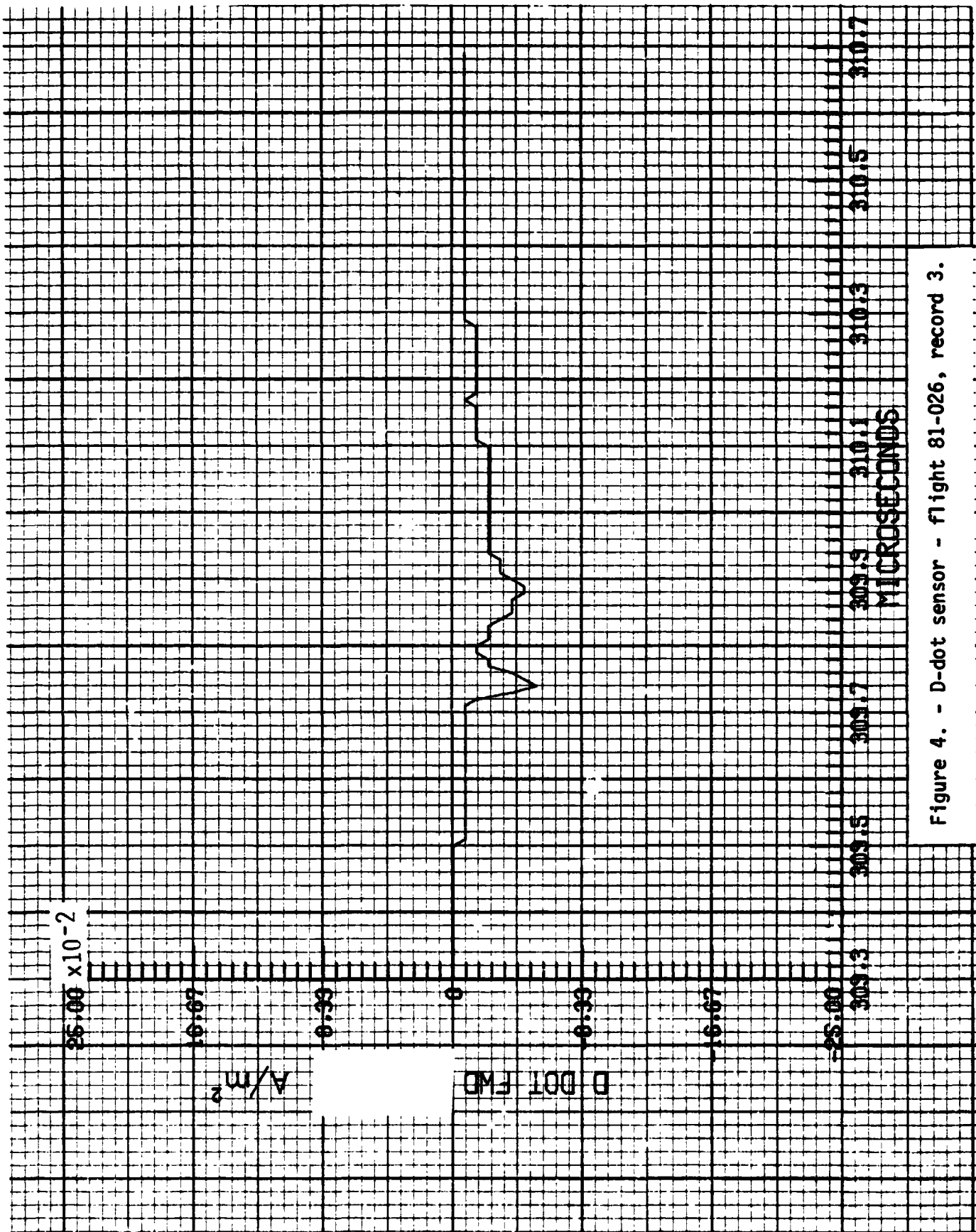


Figure 4. - D-dot sensor - flight 81-026, record 3.

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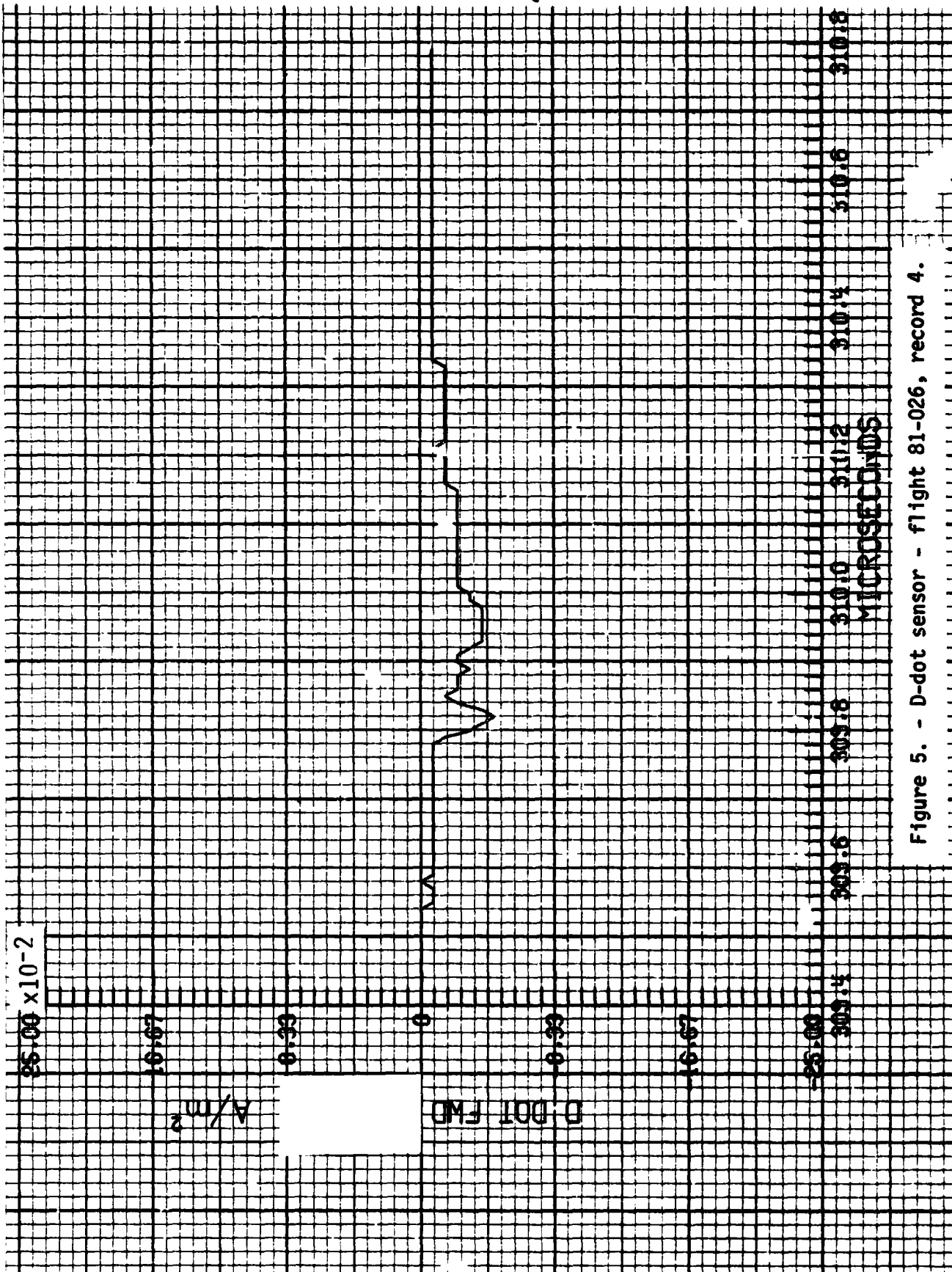


Figure 5. - D-dot sensor - flight 81-026, record 4.

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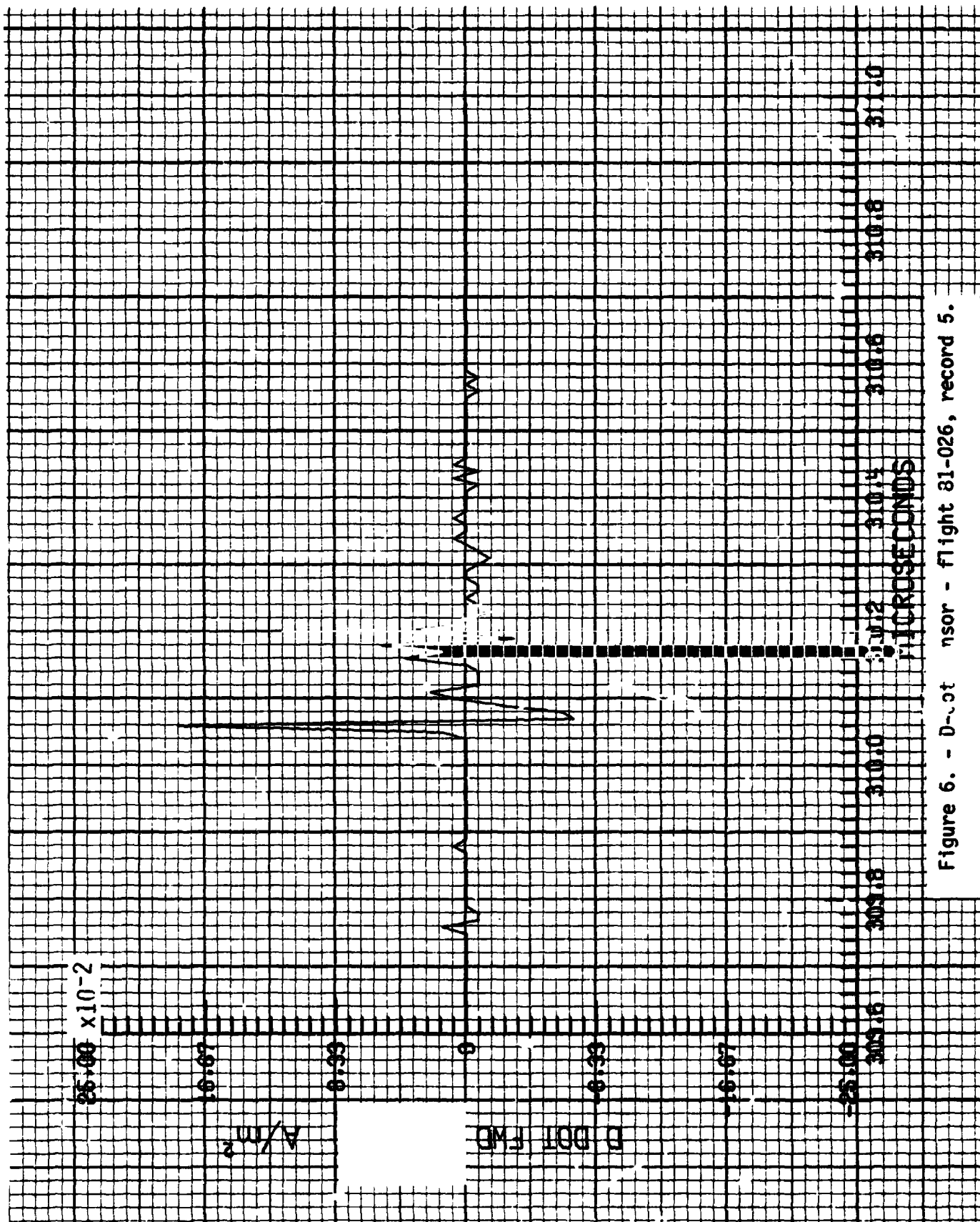


Figure 6. - D-dot nsor - flight 81-026, record 5.

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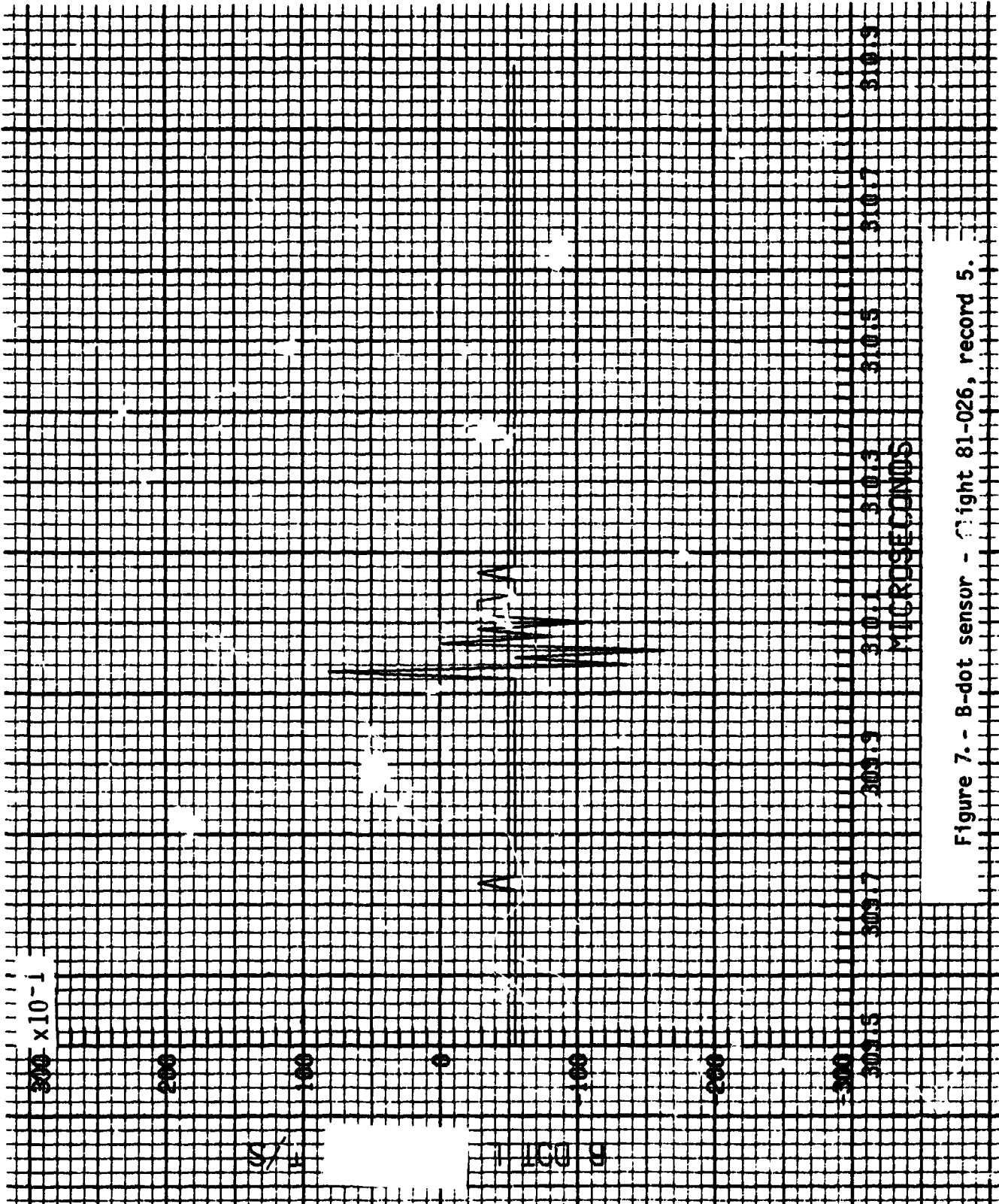


Figure 7. - B-dot sensor - Flight 81-026, record 5.

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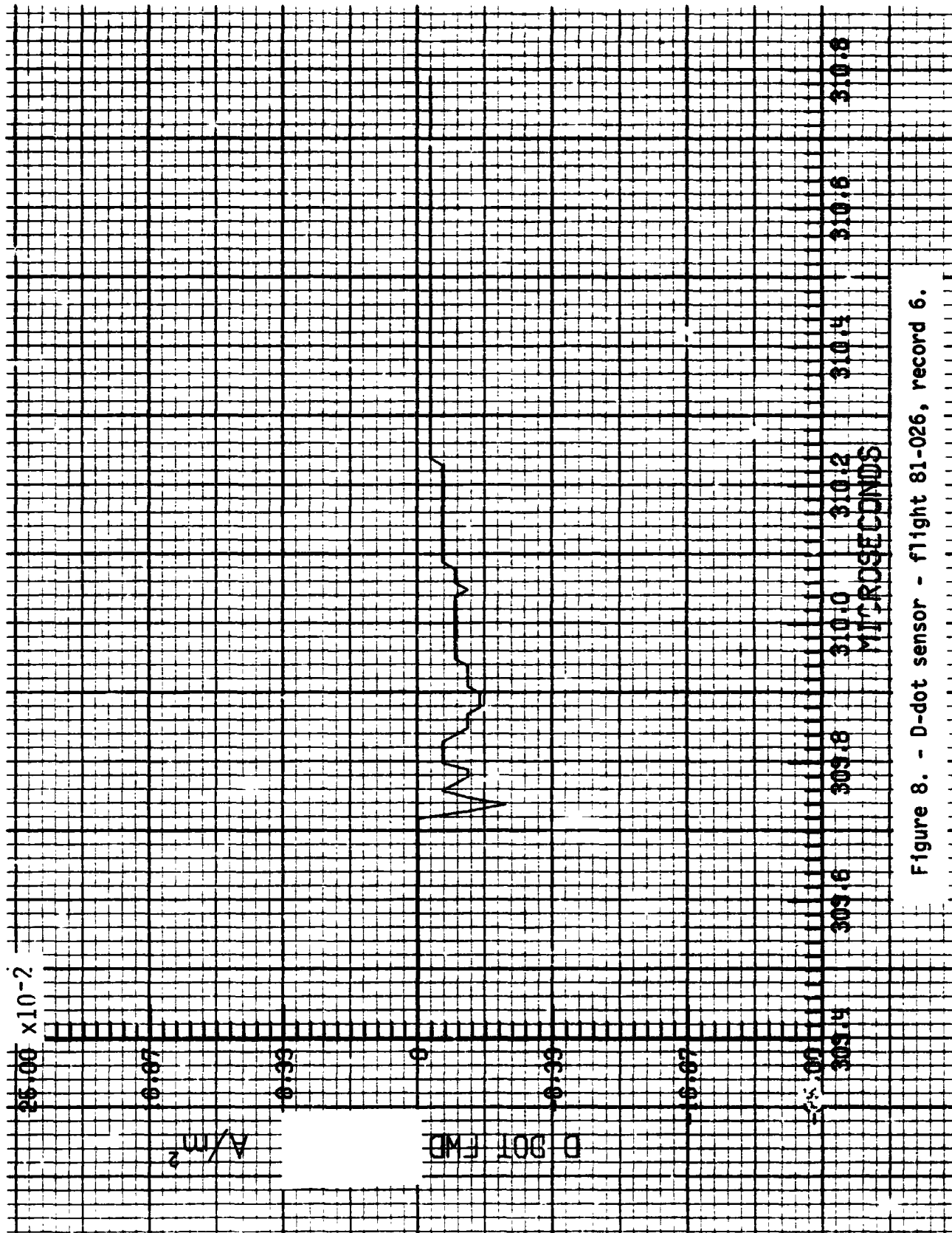


Figure 8. - D-dot sensor - flight 81-026, record 6.

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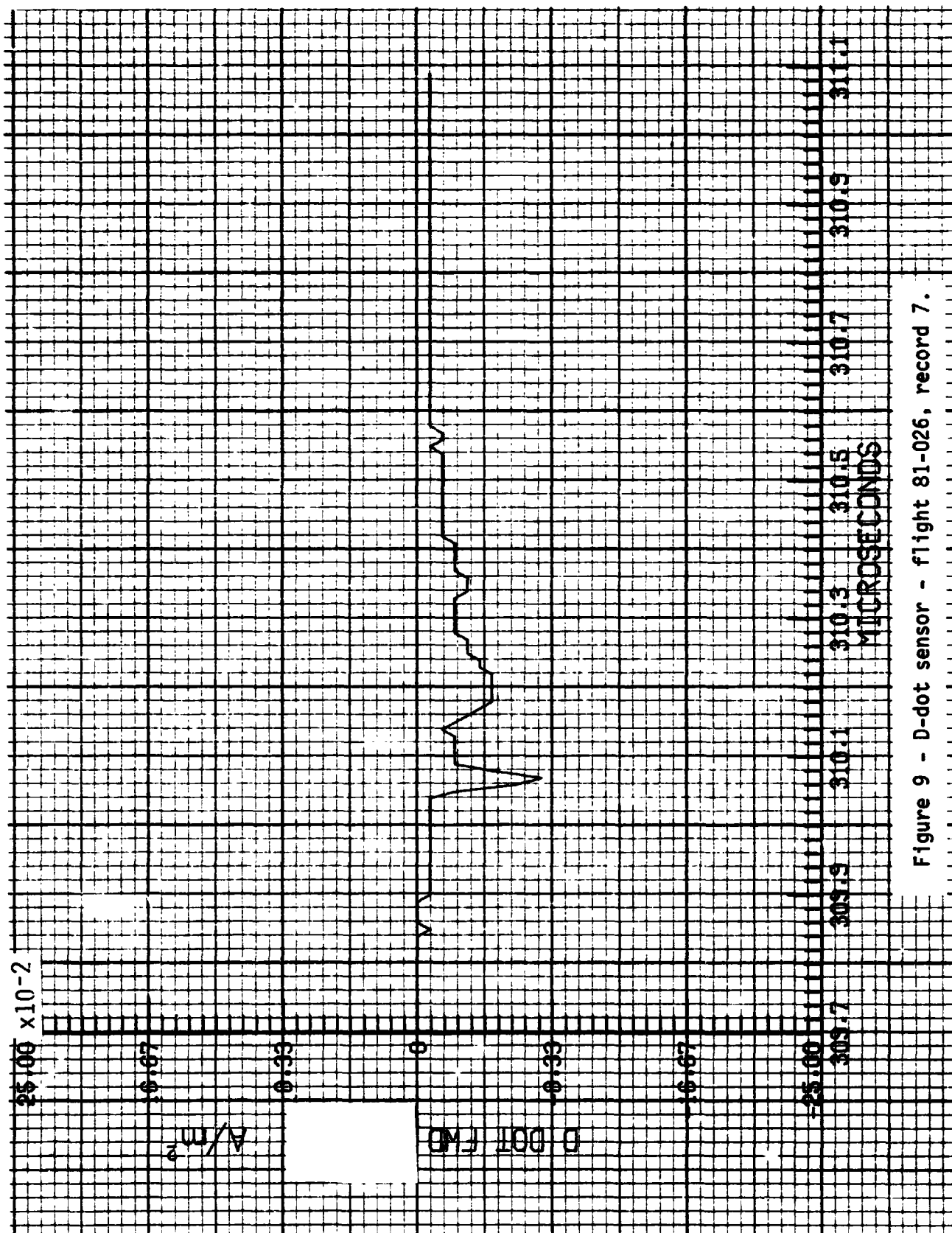


Figure 9 - D-dot sensor - flight 81-026, record 7.

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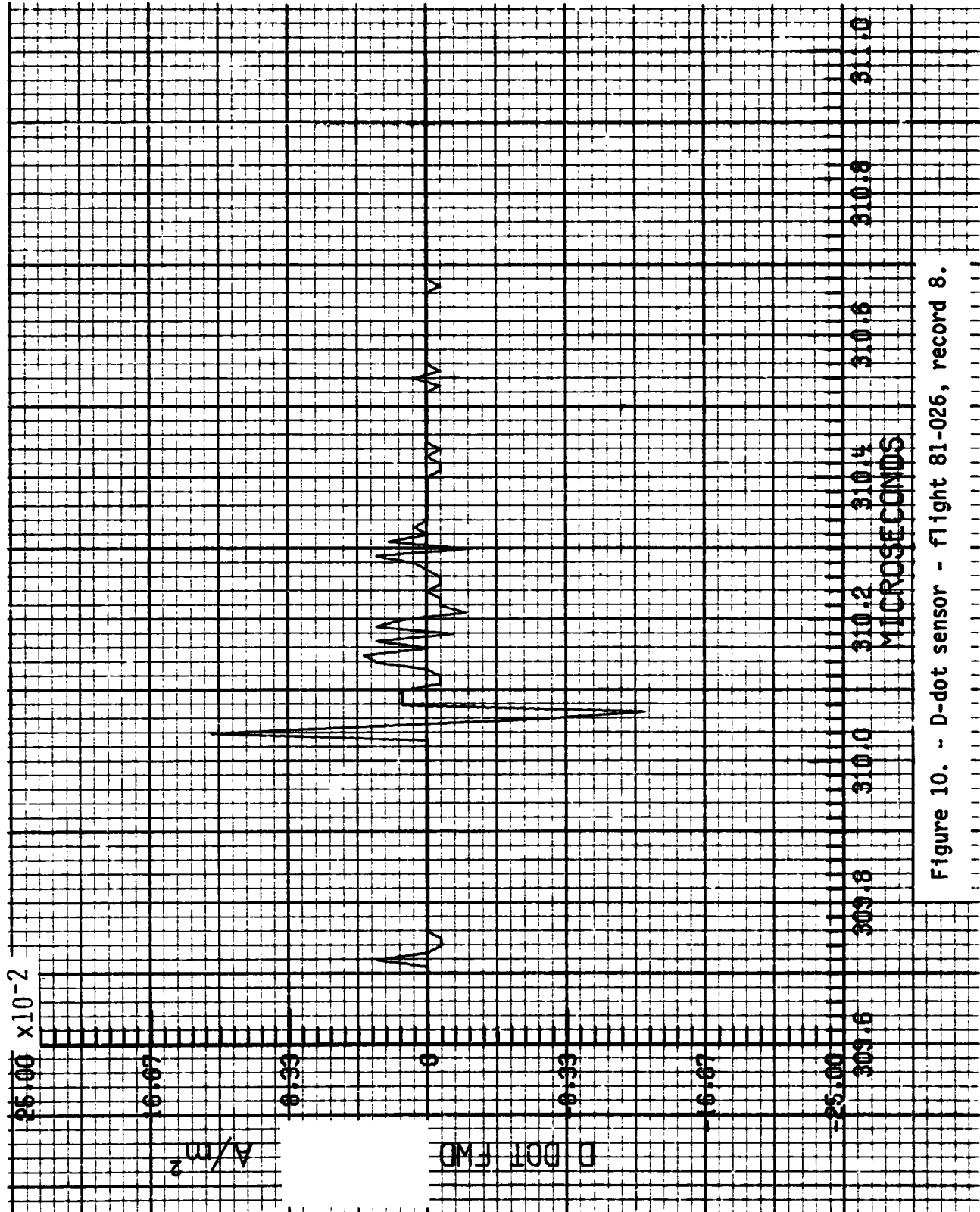


Figure 10. ~ D-dot sensor - flight 81-026, record 8.



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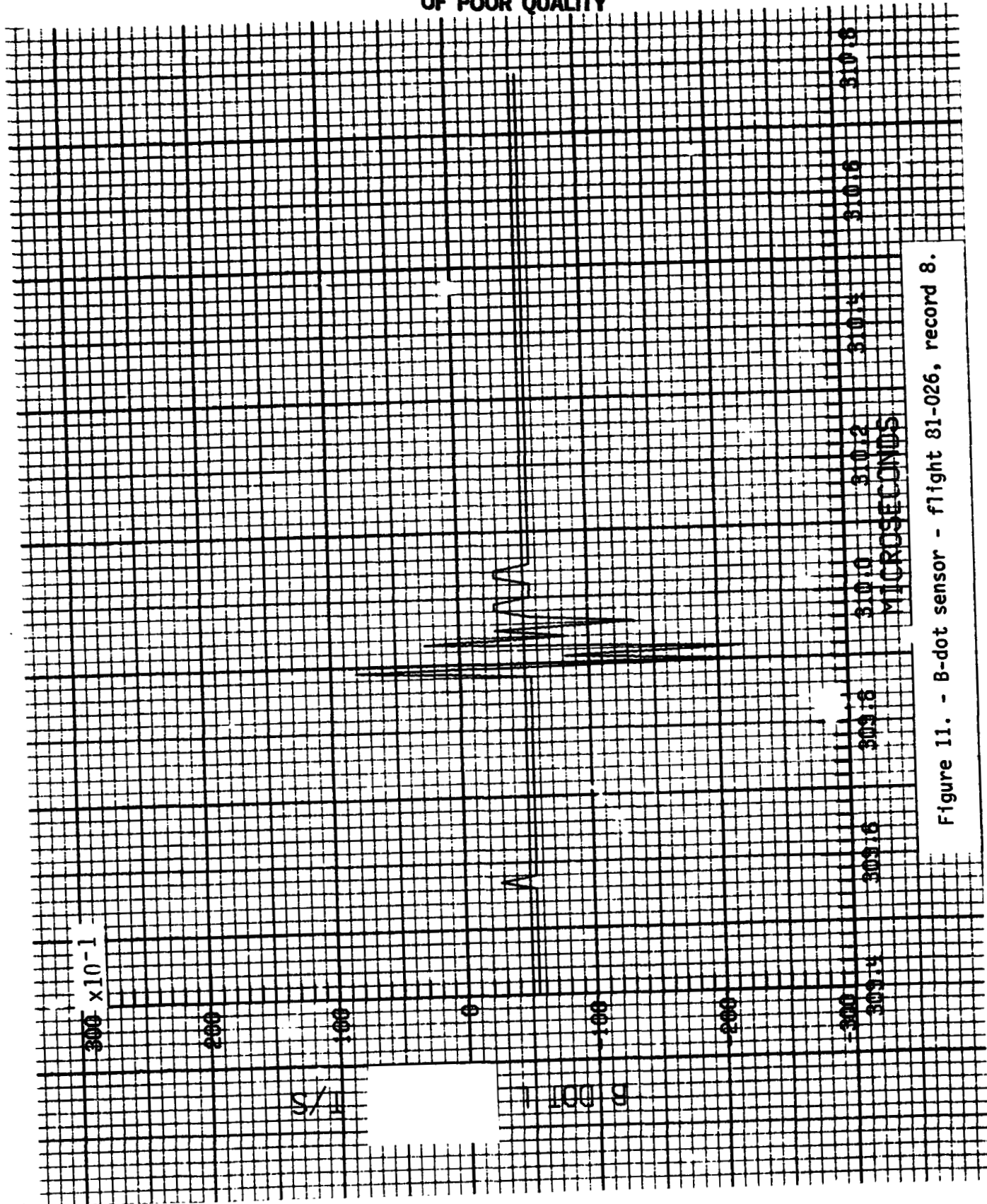


Figure 11. - B-dot sensor - flight 81-026, record 8.

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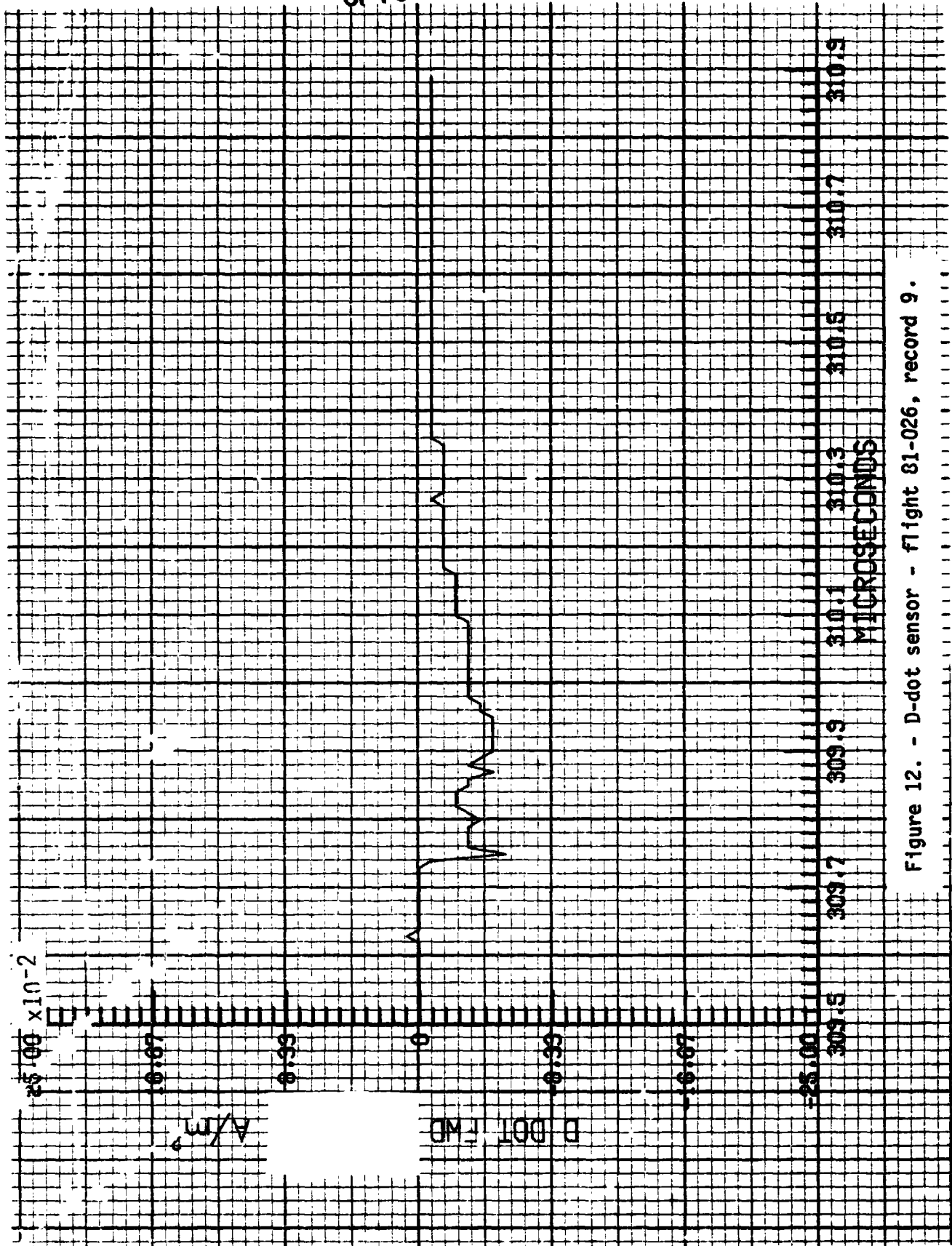


Figure 12. - D-dot sensor - flight 81-026, record 9.

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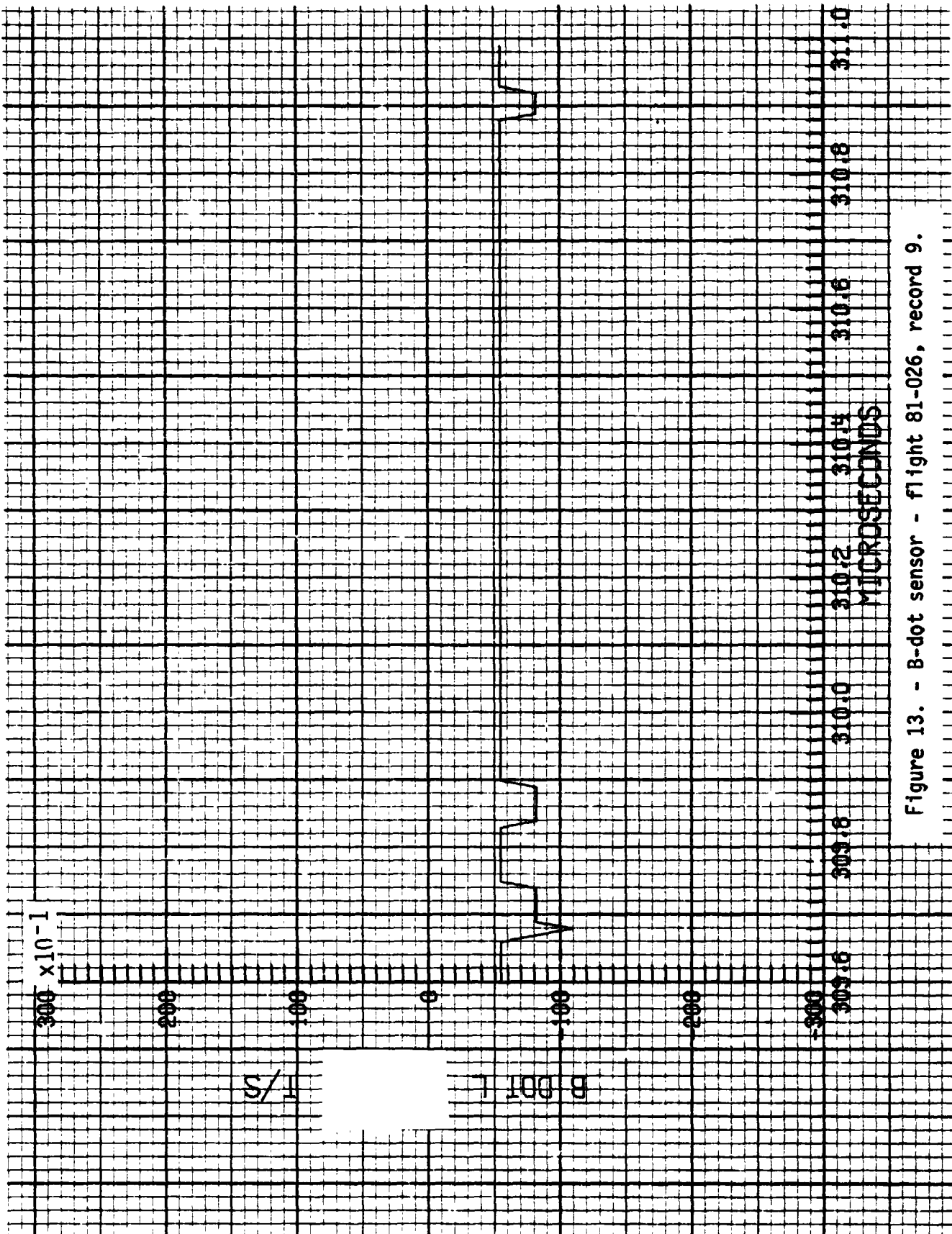


Figure 13. - B-dot sensor - flight 81-026, record 9.

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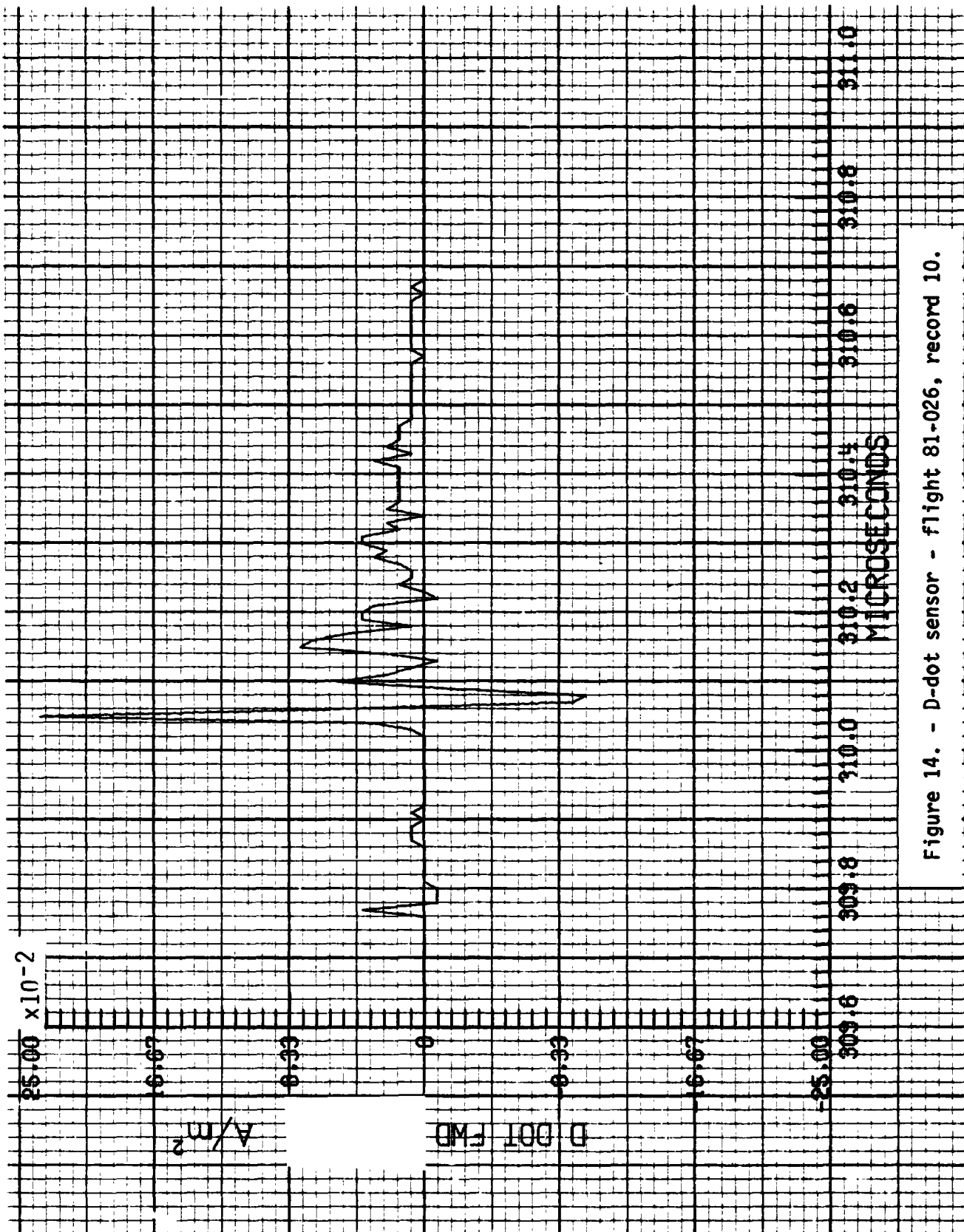


Figure 14. - D-dot sensor - flight 81-026, record 10.

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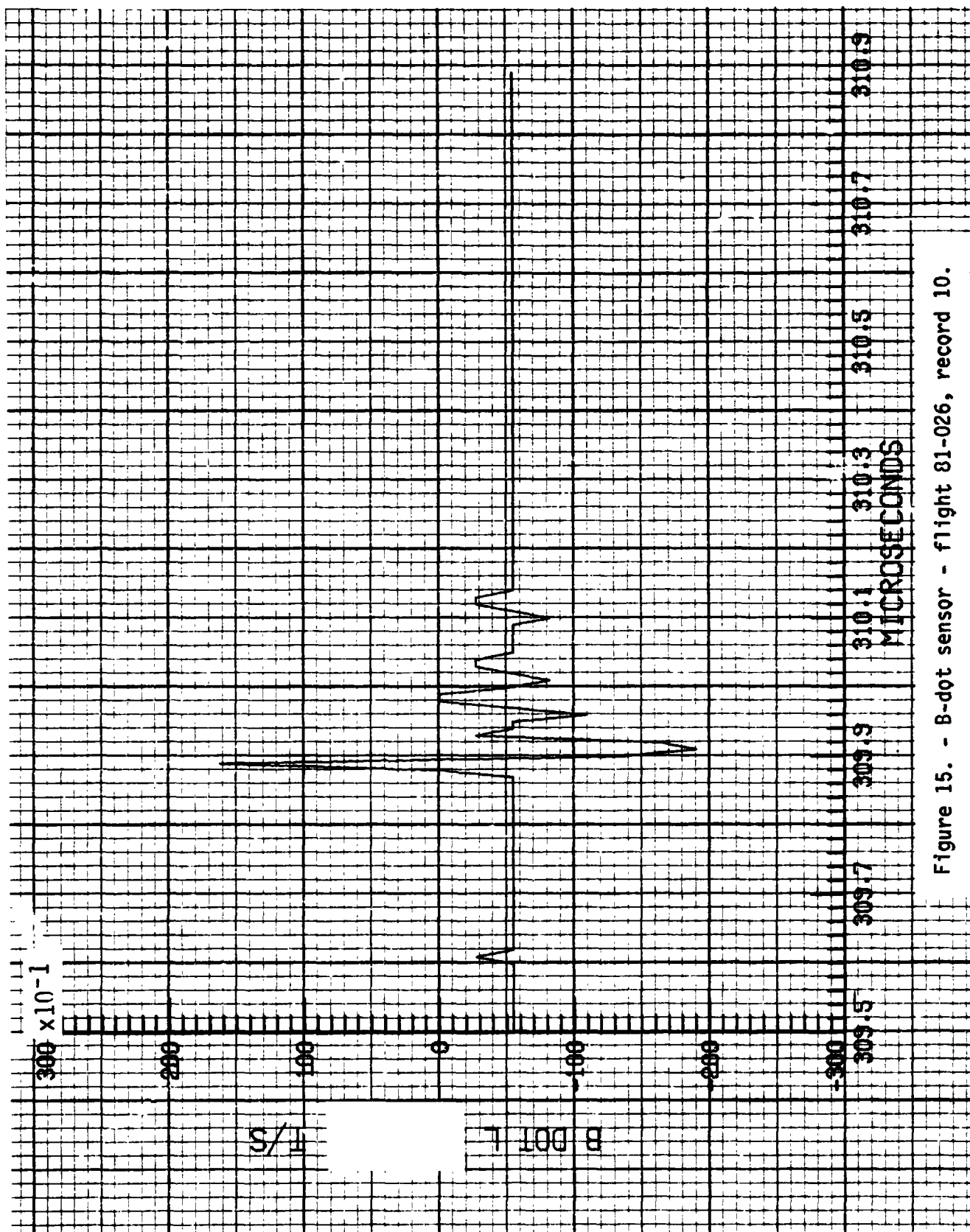


Figure 15. - B-dot sensor - flight 81-026, record 10.

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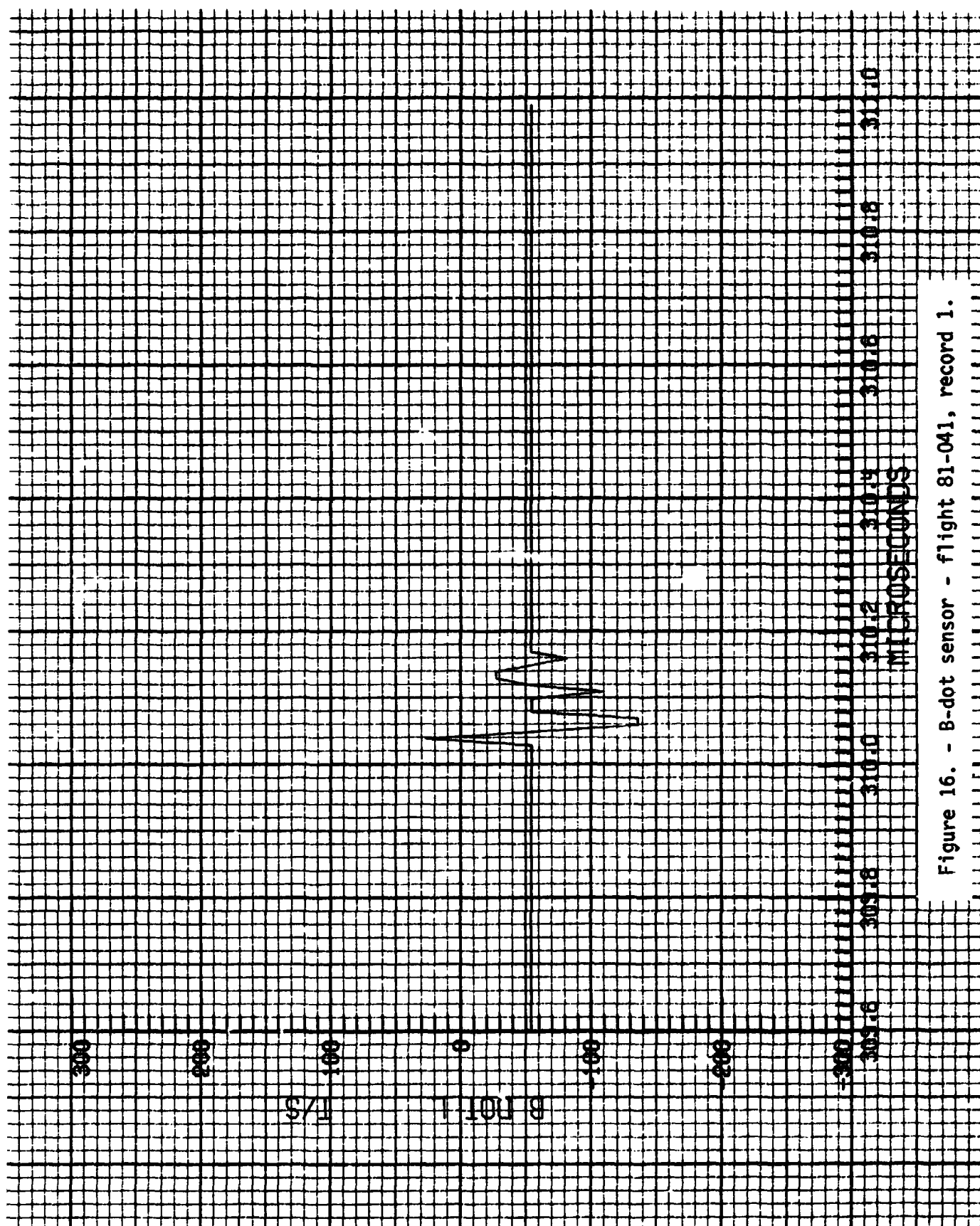


Figure 16. - B-dot sensor - flight 81-041, record 1.



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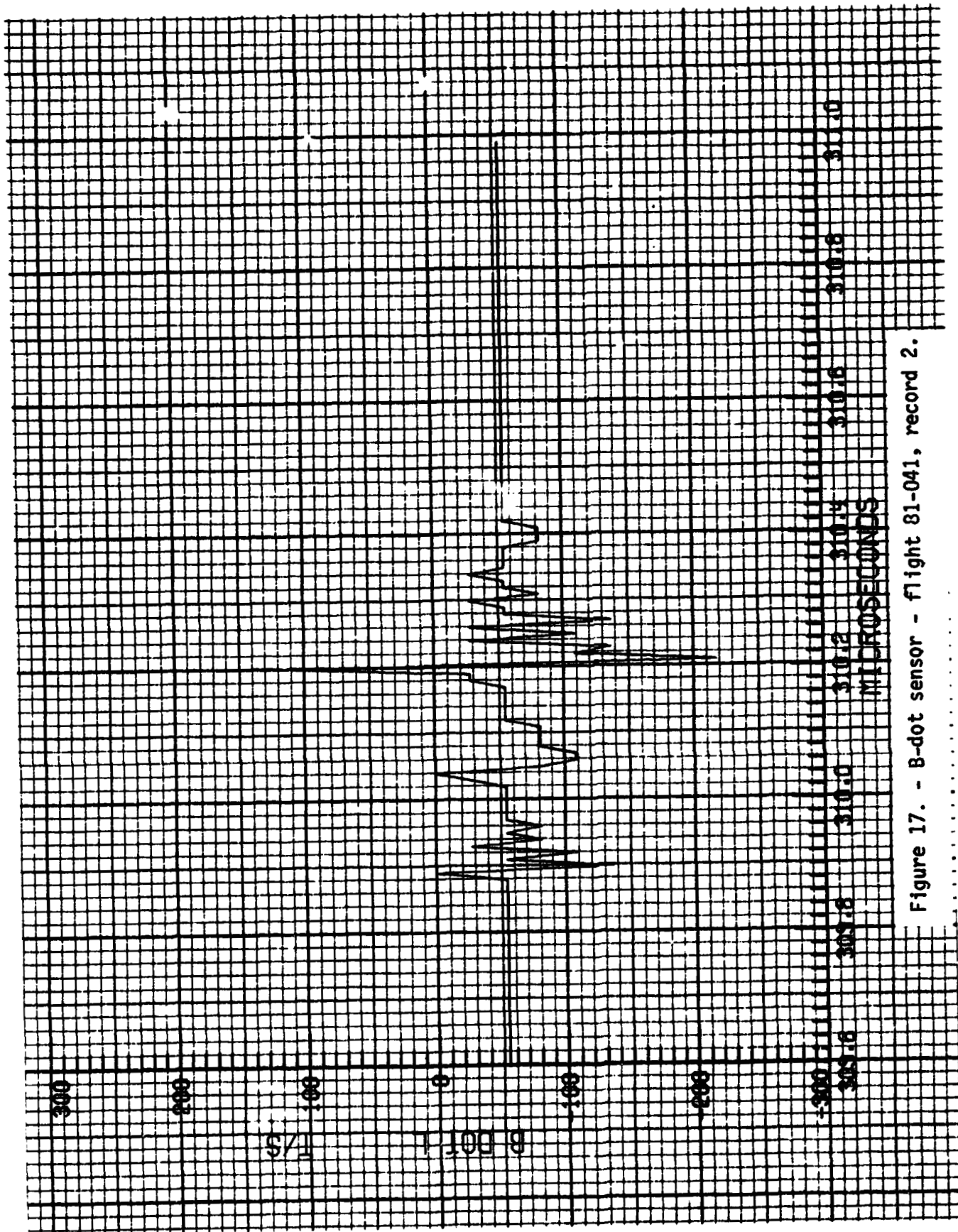


Figure 17. - B-dot sensor - flight 81-041, record 2.

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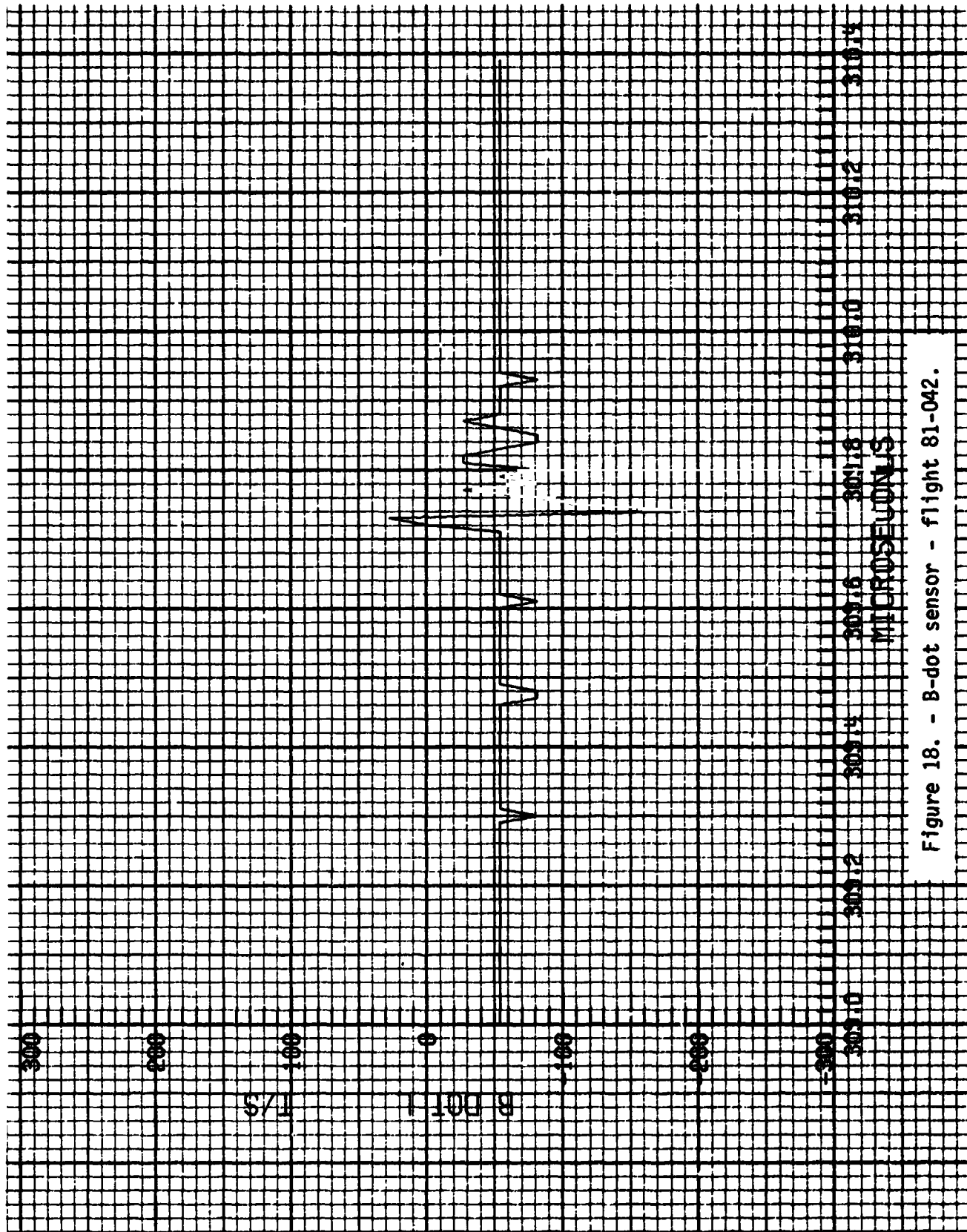


Figure 18. - B-dot sensor - flight 81-042.



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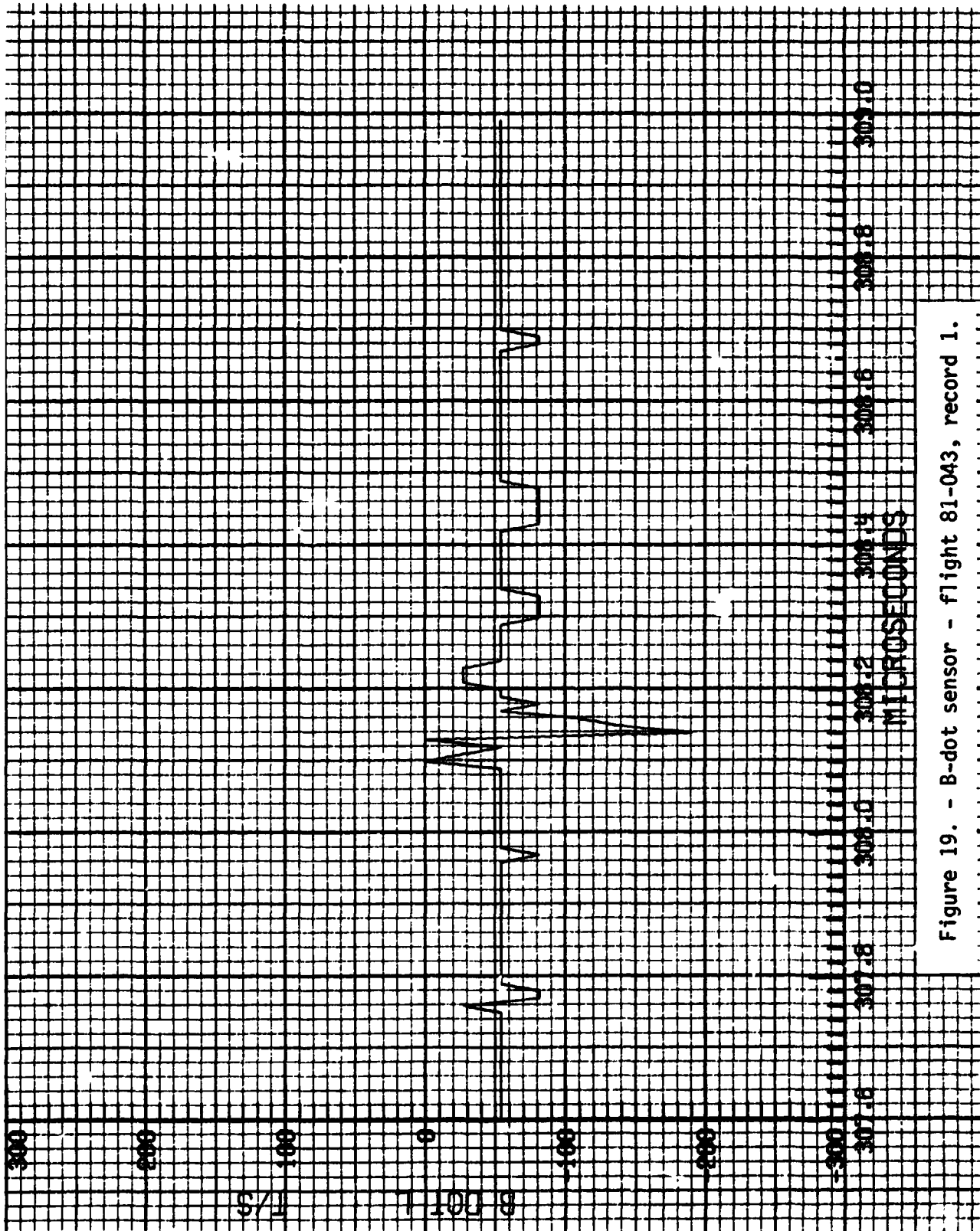


Figure 19. - B-dot sensor - flight 81-043, record 1.

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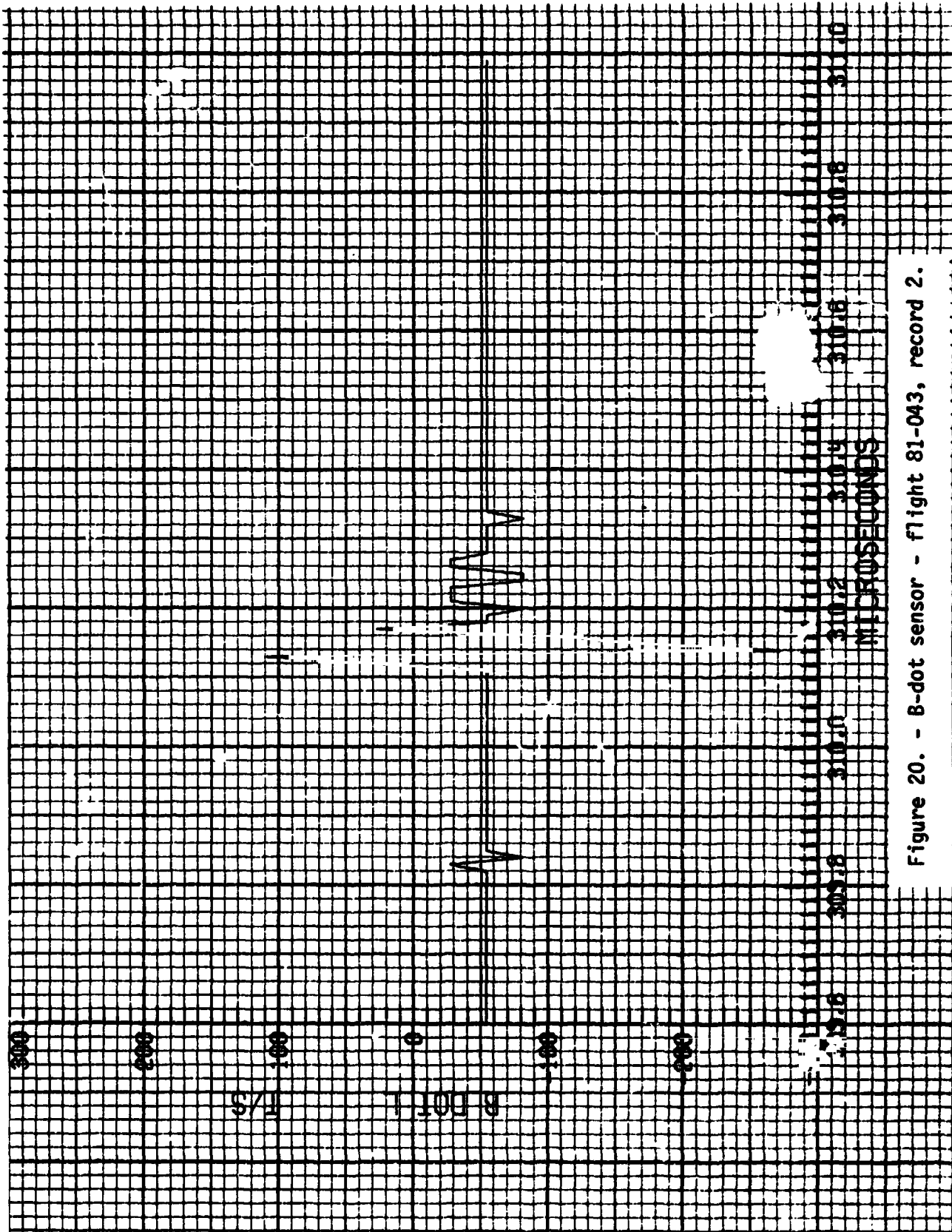


Figure 20. - B-dot sensor - flight 81-043, record 2.

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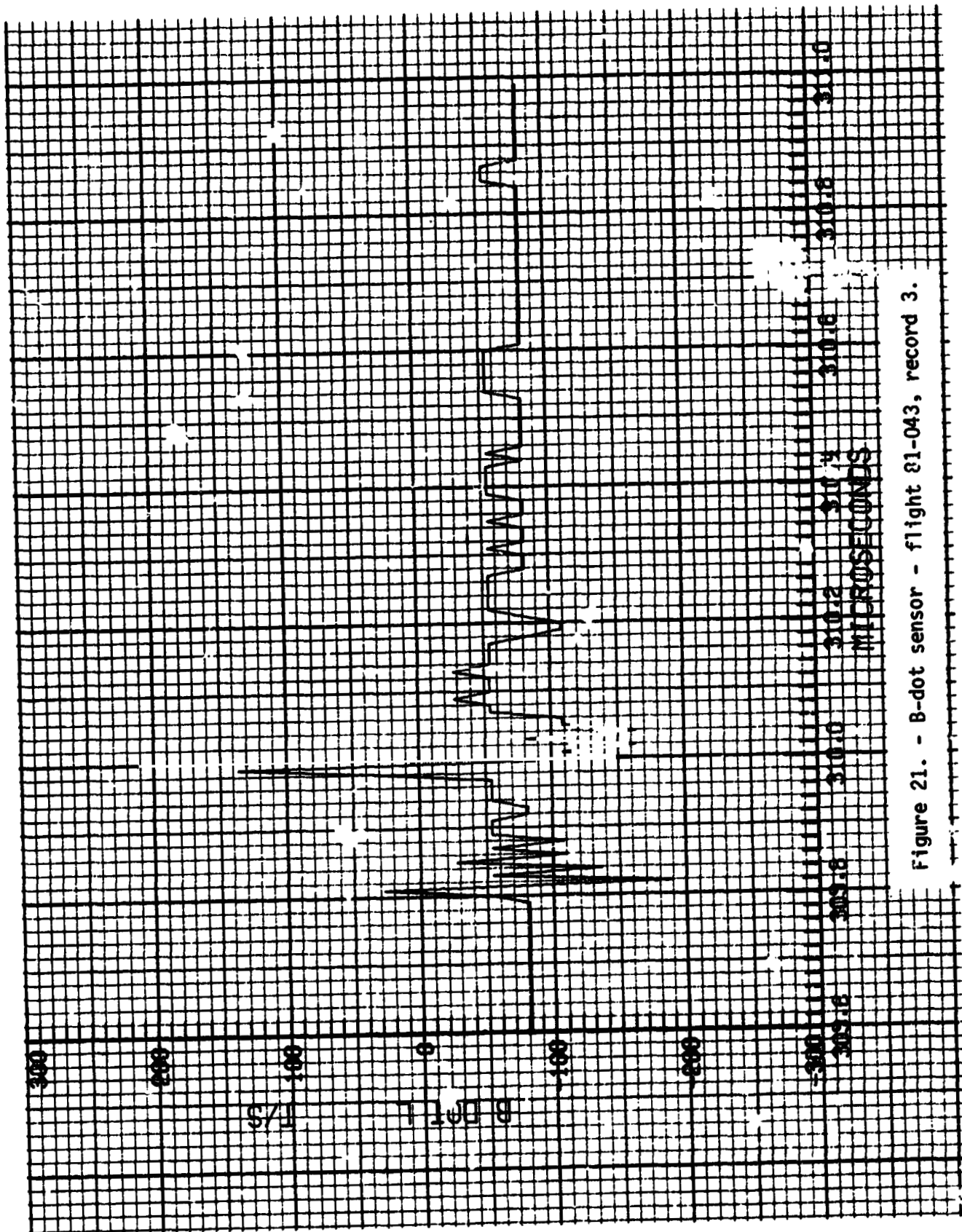


Figure 21. - B-dot sensor - flight 81-043, record 3.

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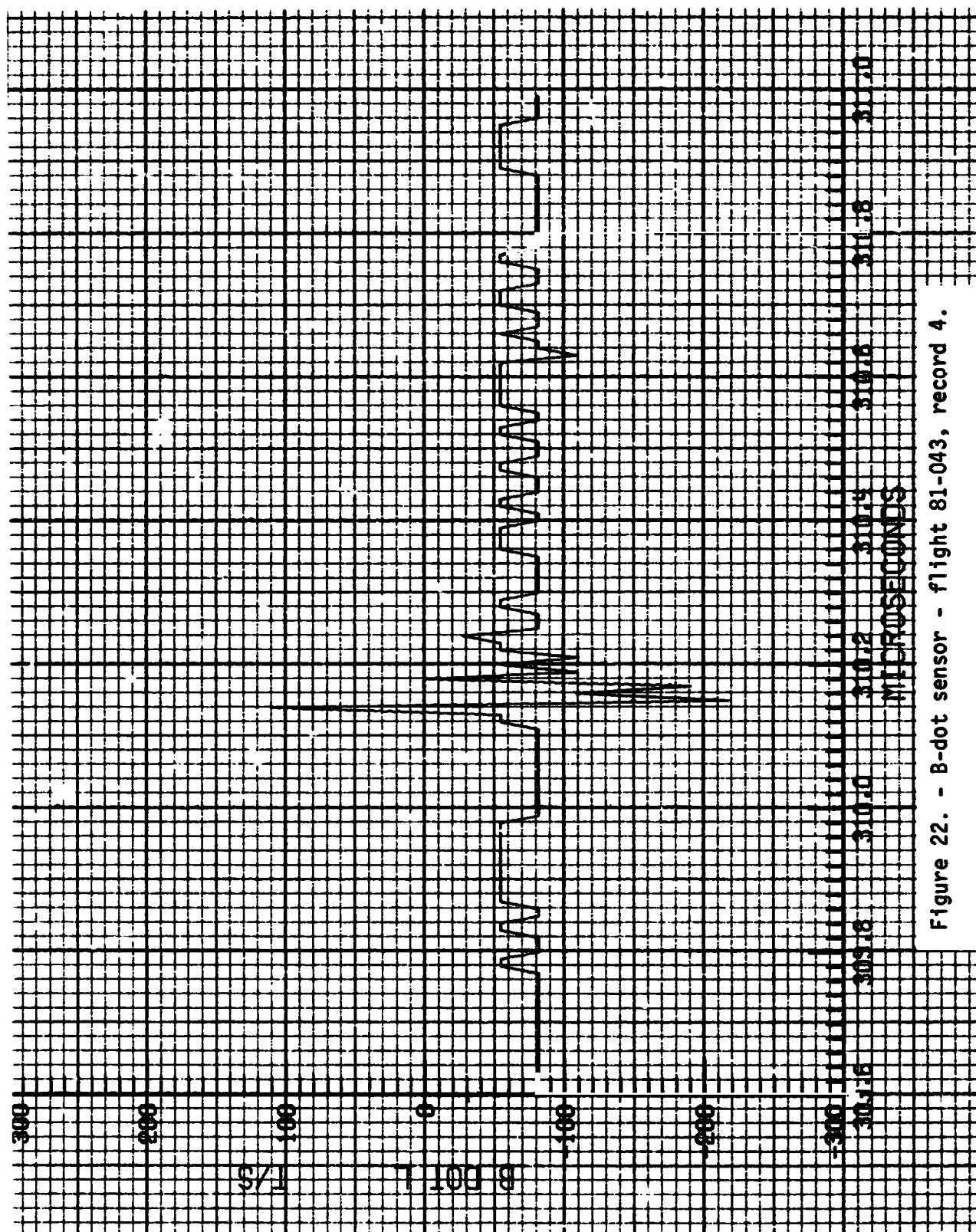


Figure 22. - B-dot sensor - flight 81-043, record 4.

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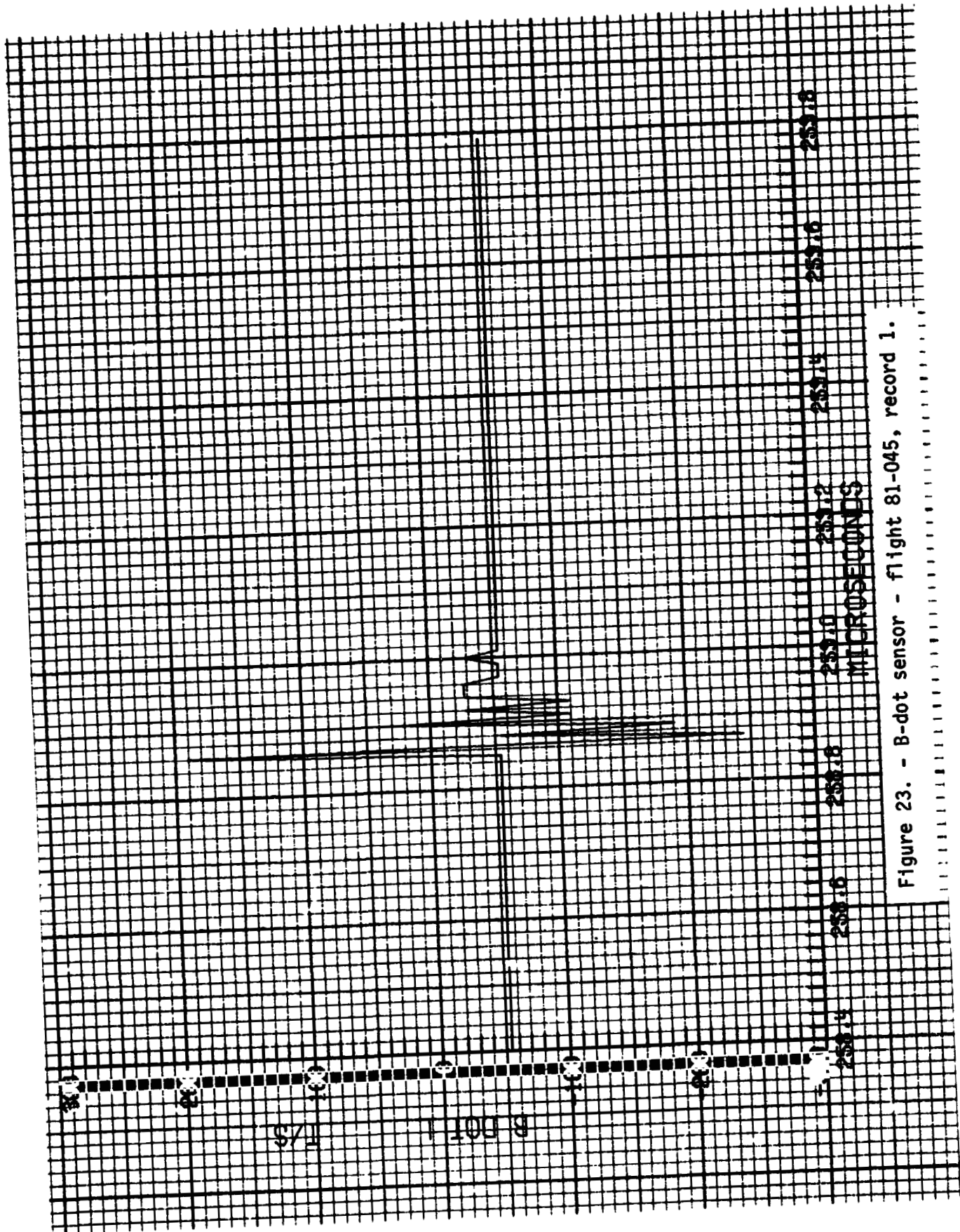


Figure 23. - B-dot sensor - flight 81-045, record 1.

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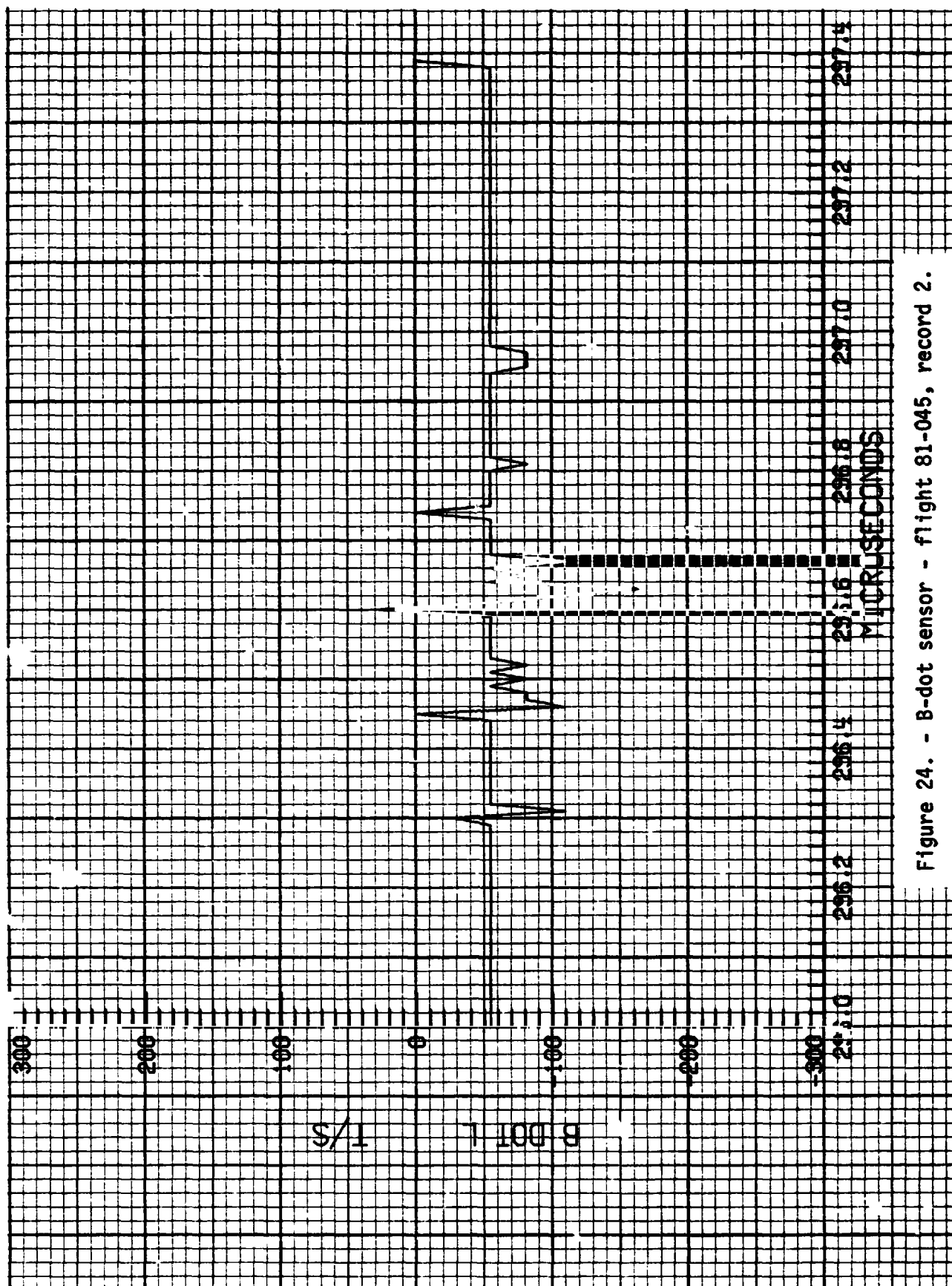


Figure 24. - B-dot sensor - flight 81-045, record 2.



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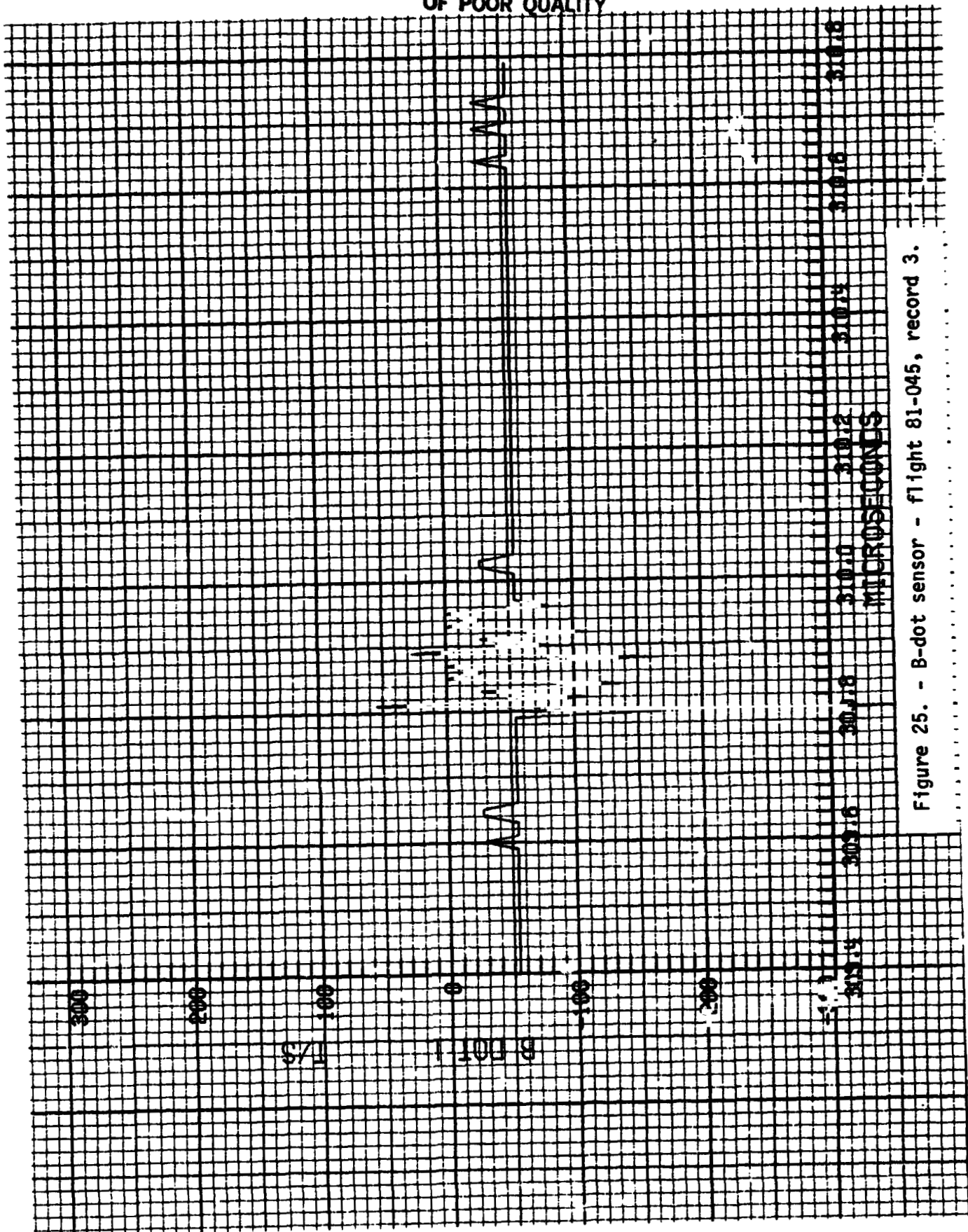


Figure 25. - B-dot sensor - flight 81-045, record 3.

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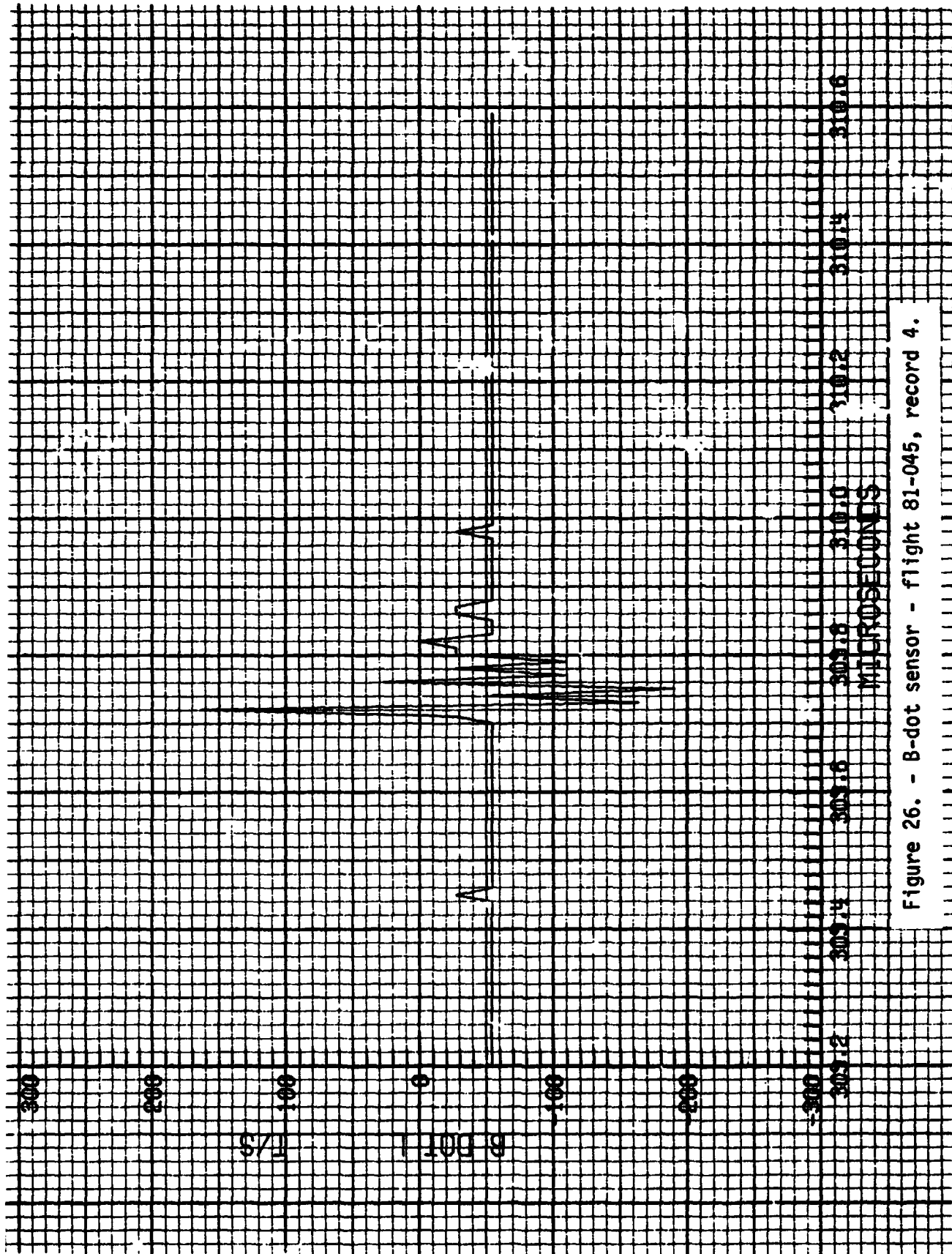


Figure 26. - B-dot sensor - flight 81-045, record 4.



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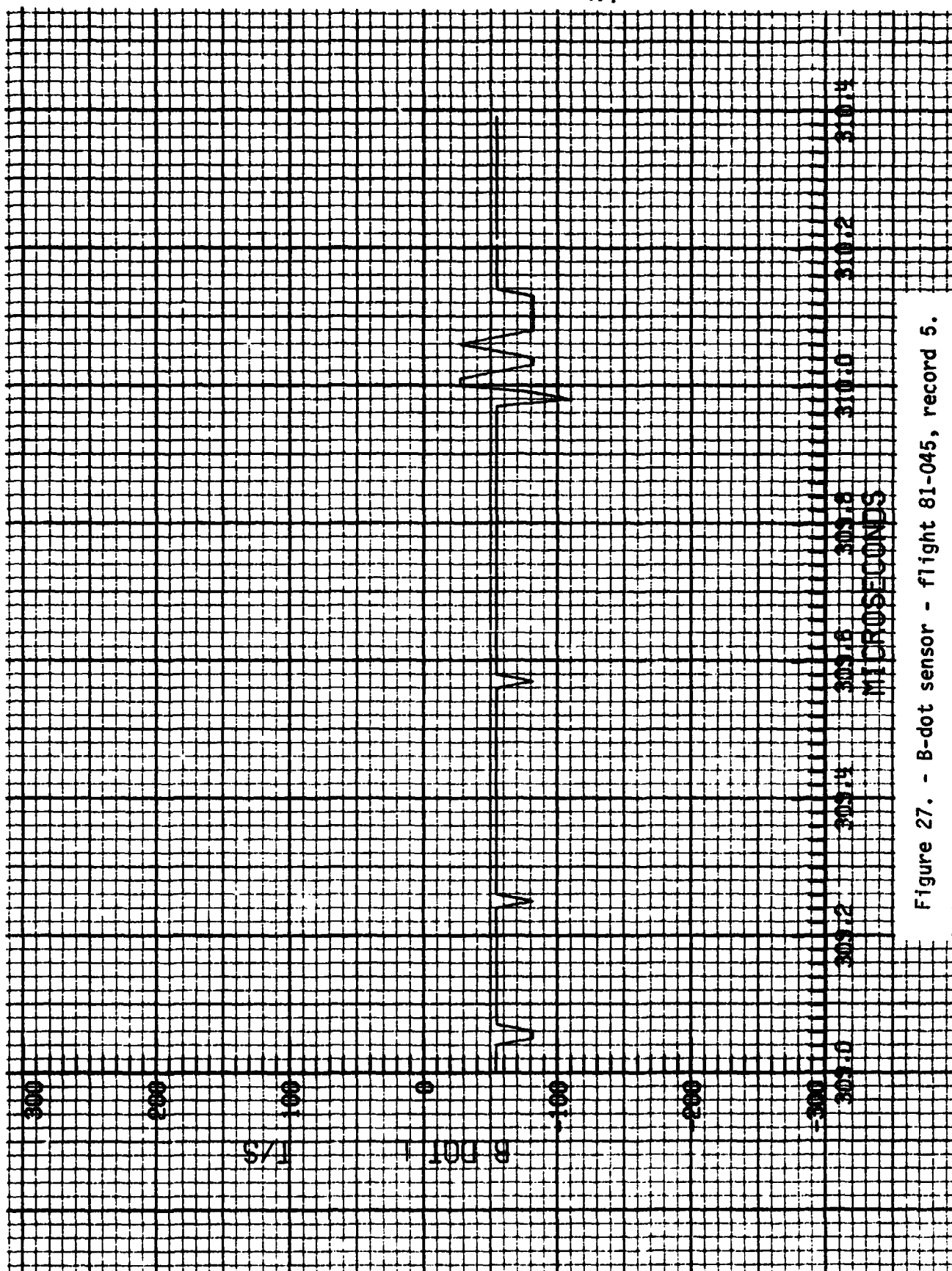
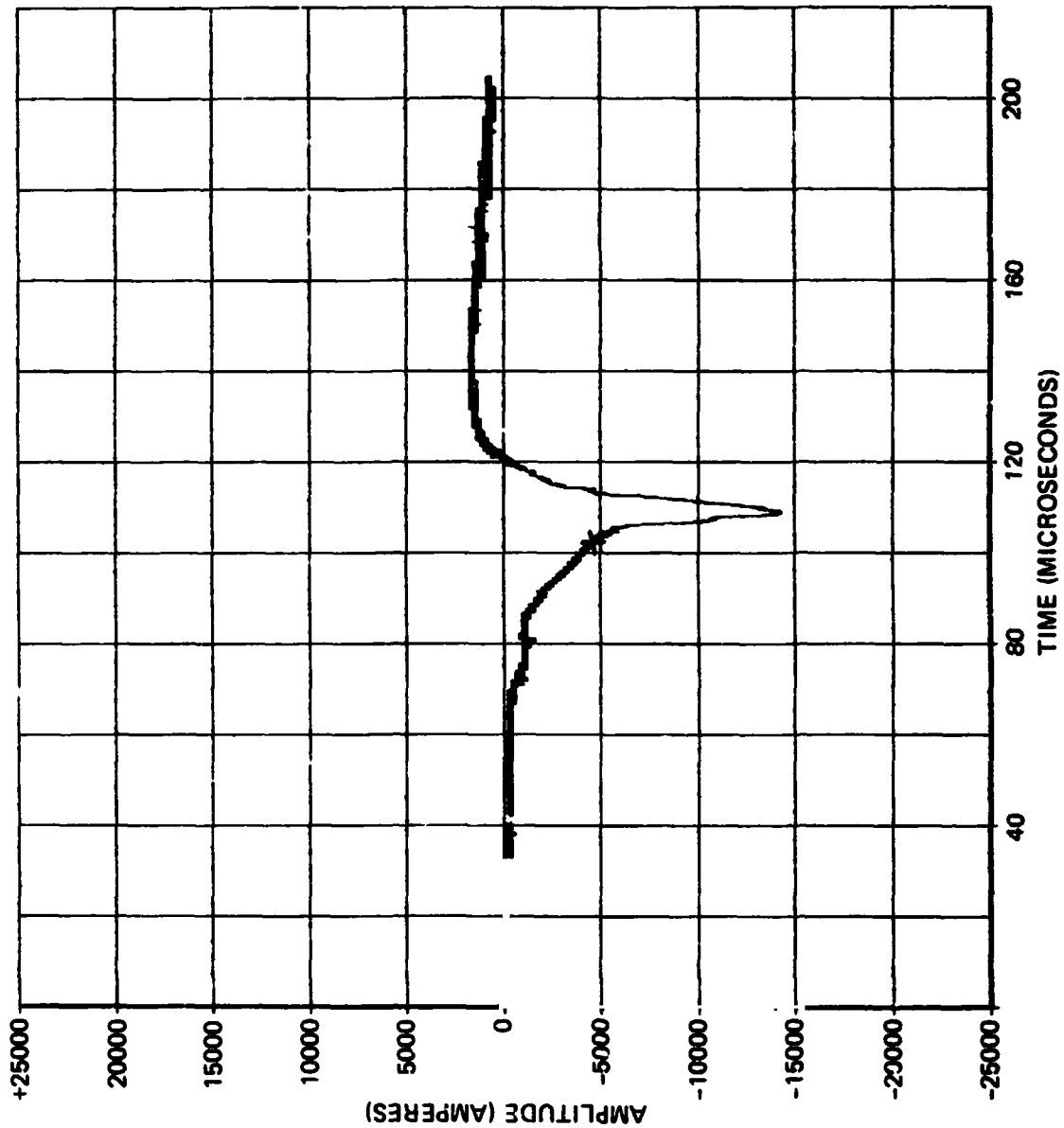


Figure 27. - B-dot sensor - flight 81-045, record 5.

TIME: 19:18:39 DATE: AUGUST 9, 1981  
LOGGER NUMBER: F-106 FLIGHT NUMBER: 43



X - INDICATES TRIGGER POINT

Figure 28. - Current sensor - flight 81-043.

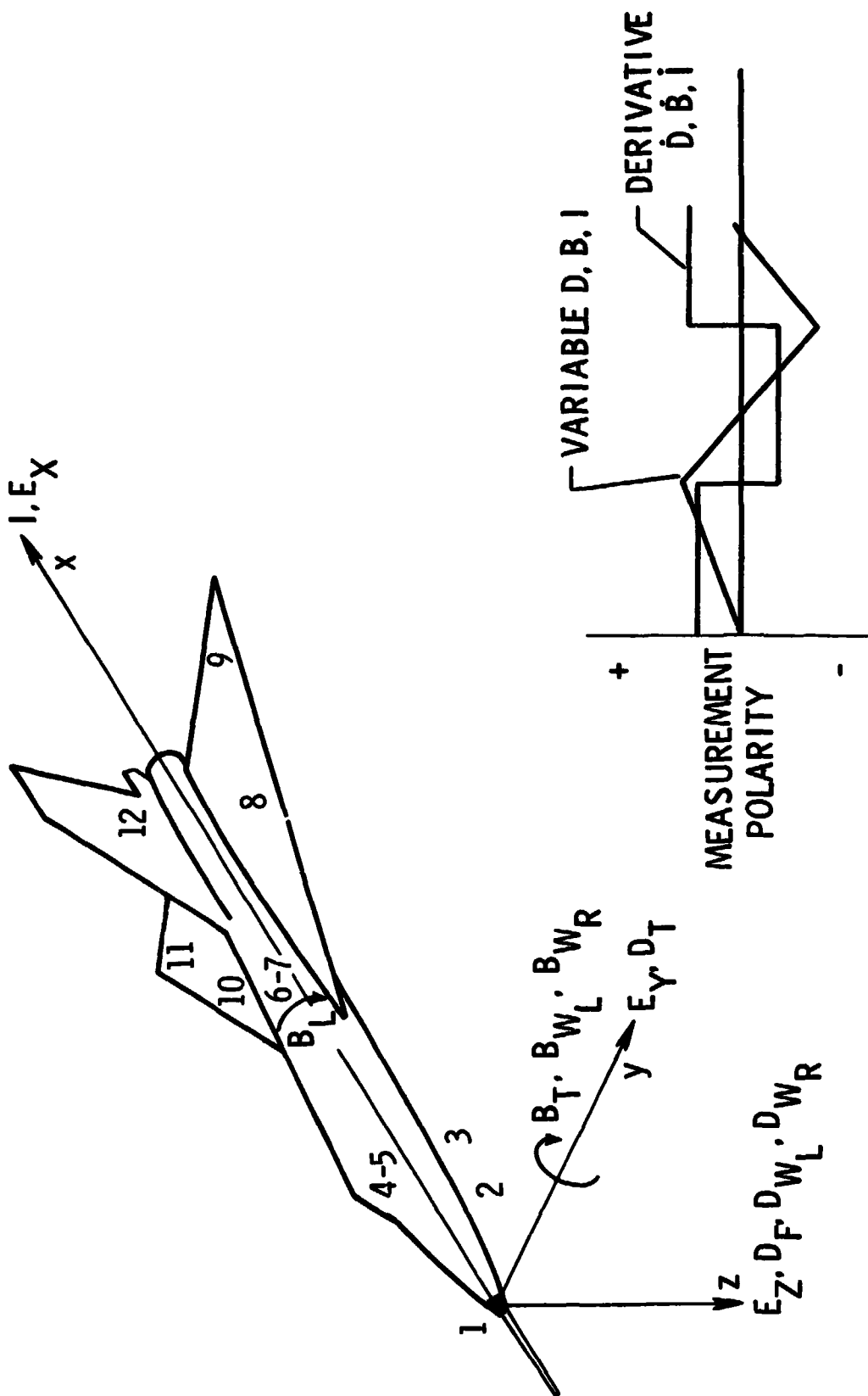


Figure 29. - Electromagnetic sign conventions and sensor locations.





Figure 32. - Lightning attachment points - flight 81-043.

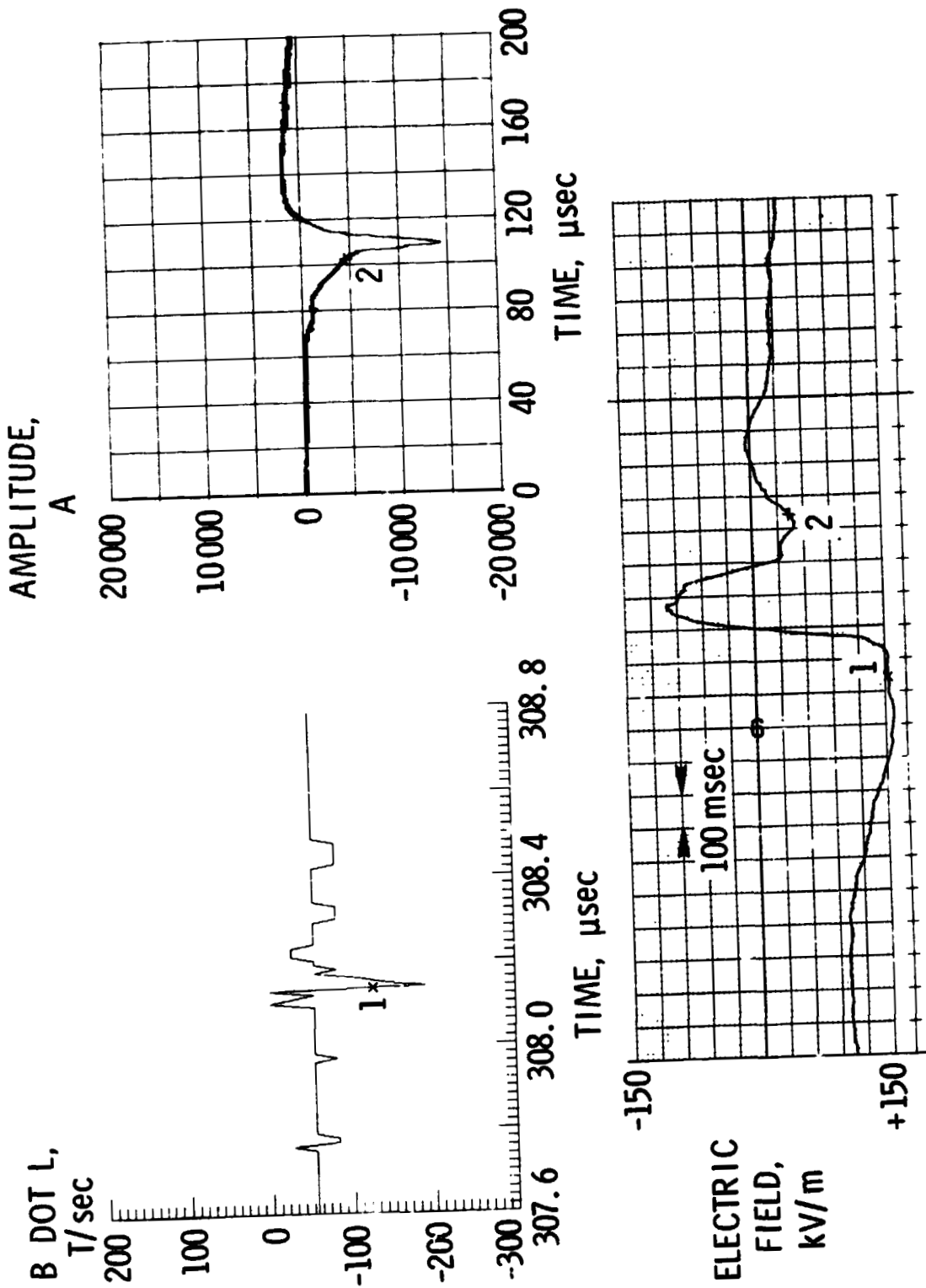


Figure 33. - Pitot boom strike waveforms.